Appendix 5.7-E

Spring/Fall 2002 Avian Radar Studies for the Cape Wind Energy Project

APPENDIX 5.7-E
SPRING/FALL 2002 AVIAN RADAR STUDIES
FOR THE
CAPE WIND ENERGY PROJECT
NANTUCKET SOUND

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EXECUTIVE SUMMARY

Radar studies were conducted to determine the abundance and behavior of birds that migrate through, forage in, and rest in the Project Area to assess potential Project-related risk to birds. Although radar data has not been validated as a reliable means of assessing risk to birds, it can provide information about abundance and behavior of birds at times of day and in places where direct visual observations are not possible. In that way, radar information, when considered with other data sources, may help to assess risk. Behaviors examined via radar included flight in various weather conditions (clear, foggy, and rainy), height and direction of flight, and characteristics of flight during day and night. The radar studies were conducted during spring migration (May 8 to June 7, 2002) and fall migration (September 3 to 30, 2002), corresponding to the peak migration periods of most night migrating neotropical songbirds and shorebirds.

An avian radar specialist, Geo-Marine, Inc., utilized a Mobile Avian Radar System (MARS) to collect data on the movement of birds in the area. MARS simultaneously employs two standard marine radar systems for detecting birds (see Appendix 5.7-J). The first radar, referred to as "TracScan" (a Furuno 1420, 30 kW, S-band [9.8 cm wavelength]) rotates horizontally through 360 degrees, to detect targets out to 4 nautical miles, measuring bird size, flight speed and direction. The second radar, a "VerCat" (a Furuno 1525, 25 kW, X-band [3.2 cm wavelength]), is tilted on its side to scan vertically and rotates in an east-west direction. The VerCat measures the altitude of targets passing within ¾ mile of the radar from the top of the radar up to 9,000 feet asl. The spring radar survey was conducted from a jack-up barge located on the southern edge of Horseshoe Shoal and tracked targets above approximately 23 feet asl. The fall survey was conducted from land at the tip of Cape Poge, Martha's Vineyard, and tracked targets above approximately 36 feet asl.

During aerial and boat surveys (and presumably during the radar observations), the majority of birds (mostly seabirds and other waterbirds - loons, terns, etc.) were observed on the water or flying at altitudes below the lowest range of the radar. Therefore, a large percentage of low-flying birds below the range of the rotors were probably not tracked by the radar.

The data were collected and analyzed to provide the following information about birds within the radar range:

- Numbers of birds aloft during spring and fall migration seasons
    - Types of migrants (small/slow-moving targets – mostly migrating songbirds and some foraging birds like gulls and terns) vs. larger/faster-moving targets such as waterfowl (seaducks, shorebirds, loons, cormorants, etc.)
    - Numbers and types of birds aloft in day and night
    - Numbers and types of birds aloft in different weather conditions (clear vs. fog vs. rain)
- Behavioral attributes of birds aloft during spring and fall migration seasons
    - Numbers and types of birds that fly in different altitudinal strata during day and night (specifically the approximate 75-417 foot height range of the proposed turbine rotors; also referred to as the "rotor swept zone")
    - Direction of birds during day and night
- Description and quantification of large bird concentrations (large flocks migrating) and behaviors (gulls feeding and following fishing trawlers) and a determination as to whether these represent a potential risk to the birds involved.

The number of targets observed varied by season (spring vs. fall). Almost twice as many targets were observed in fall as in spring. A total 1,052,761 targets were observed by TracScan radar (approximately 38% of these in spring and 62% in fall). A total of 491,306 targets were observed by VerCat radar (approximately 31% of these in spring and 69% in fall).

The number of targets observed also varied depending on whether the survey was conducted during day or night. Because lower fatality rates have been found for most birds migrating during daytime hours, the behavior of night flying birds, primarily migrants, is given more attention in the analyses that follow. Risk to daytime fliers is likely to be lower, as has been demonstrated in previous studies (Kerns and Kerlinger 2004, Nicholson 2003).

To assess the potential for collision risk with the proposed WTGs, the proportion of birds flying within the rotor height zone (75-417, or 23-127 m, feet asl) was examined. The majority of birds tracked by radar at night were at heights above the rotor swept zone (approximately 89% in fall and 68% in spring). Of those targets observed by VerCat, 127,697 (approximately 26%) were observed in the rotor swept zone, with 83,083 out of 221,059 (approximately 38%) observed during the day and 44,614 out of 270,247 (approximately 17%) observed at night in the rotor swept zone. It is important to note that greater than 95% of the birds where altitude was estimated during aerial and boat-based surveys in Nantucket Sound in 2002 and 2003 were outside the rotor swept zone. The vast majority (>90%) of birds observed during these surveys were below 20 feet, either on the water or flying just above the water and therefore would not have been detected by radar.

Most birds tracked with the TracScan radar were observed when weather was clear (no rain and/or fog). In fall, 72% (night) to 88% (day) of slow targets – and 66% (night) to 90% (day) of fast targets – were observed during clear weather. Similar percentages of targets observed during clear weather were found in spring: 59% (night) to 82% (day) for slow targets, and 53% (night) to 79% (day) for fast targets. It was not possible to determine whether the birds that were flying during inclement weather were flying above fog or rain.

Of the targets observed by TracScan, the majority were small birds (mostly songbirds or small shorebirds) or slow-moving birds (gulls, terns, and others that were probably foraging or soaring over the water). Slow targets (mostly small songbird migrants and foraging birds) outnumbered fast targets (waterfowl, loons, cormorants, shorebird flocks, etc.) by approximately 3:1 in the spring and by approximately 2:1 in the fall. During fall, there was little difference between passage rate of fast vs. slow targets in daytime, although at night there were three times more slow targets than fast targets. The rate for slow birds in the fall at night was more than twice the daytime rate, whereas nighttime rates for fast birds in the fall were similar to daytime rates. Both spring and fall rates of slow and fast targets (primarily migrants, as opposed to many nonmigrants during daytime) at night (53.3 in spring, 134.5 in fall) per hour per kilometer of front were equal to or lower than migration rates derived from radar and ceilometer studies of migration in New York, Vermont, and Maine, but much lower than migration traffic rates reported from the southeastern United States. This strongly suggests that concentrations of night migrating birds that cross Nantucket Sound are similar to or less than migration passage rates further inland.

Flight direction during both spring and fall varied greatly among individuals and groups of birds. The mean direction of flight during spring for slow moving targets was bimodal with the axis being northwest to southeast. For faster, usually larger targets, the predominant direction was to the northeast. During fall, variation in flight direction was greater than in spring, with bimodal distributions evident for both fast and slow moving targets. Also in fall, slow moving targets flew mostly to the northwest and southeast, whereas fast moving targets flew mostly to the northeast and southwest.

Flight direction varied greatly, even within a migration season and within slow and fast radar targets (targets can include flocks of birds). Some of the variation among slow moving targets during daytime in spring and fall is likely attributable to foraging flights of gulls, terns (mostly fall), nonmigrants (onshore fall only), and migrants.

1.0 INTRODUCTION

In order to assess the migratory behavior and movement of birds into, out of, and through Nantucket Sound, radar studies were conducted during the spring and fall migration periods by Geo-Marine, Inc in 2002. The data collected and summarized by Geo-Marine, Inc. were used to compile this report (see Appendix 5.7-J)

Radar studies were requested by various environmental organizations and wildlife agencies as a means of assessing risk, primarily to songbirds and other birds that migrate through the Nantucket Sound area and more specifically at the Wind Park Site located on Horseshoe Shoal. There have also been requests to evaluate risk to birds during inclement weather. Although radar has been used at many different sites to study bird movements at proposed wind power facilities, it has not yet been demonstrated to be a reliable or valid predictor of high or biologically significant collision risk to birds at wind power facilities. Therefore, the ability to predict or assess the potential for high risk based on radar data has not been validated. However, radar can provide an indication as to the number and behavior of birds that use an area in a more thorough and efficient manner than other technologies, especially with respect to night migrating species. With this in mind, this report describes a radar study undertaken in Nantucket Sound that will be used to examine potential risk to birds during Project operation.

Radar has the ability to detect birds at greater ranges than the human eye (even when assisted with binoculars), as well as to measure behavioral attributes of birds. For example, radar can detect birds at several miles during a variety of conditions in fog, and even, sometimes, rainy conditions. Radar can also measure altitude, speed and flight direction.

Marine surveillance and vertical radars were used to measure the numbers of birds present within the radar range during spring and fall migration periods, as well as their behavioral patterns when present. The data were collected and analyzed to provide the following information:

- Numbers of birds aloft during spring and fall migration seasons
  - Types of migrants (small/slow-moving targets – mostly migrating songbirds and some foraging birds like gulls and terns) vs. larger/faster-moving targets such as waterfowl (seaducks, shorebirds, loons, cormorants, etc.)
  - Numbers and types of birds aloft in day and night
  - Numbers and types of birds aloft in different weather conditions (clear vs. fog vs. rain)
- Behavioral attributes of birds aloft during spring and fall migration seasons
  - Numbers and types of birds that fly in different altitudinal strata during day and night (specifically the approximate 75-417 foot height range of the proposed turbine rotors)
  - Direction of birds during day and night
- Description and quantification of large bird concentrations (large flocks migrating) and behaviors (gulls feeding and following fishing trawlers) and a determination as to whether these represent a potential risk to the birds involved.

Of particular interest was determining how many (relative and absolute numbers) birds of different types were aloft over Nantucket Sound in fog and rain conditions during both day and night. These numbers are thought by some to suggest the potential degree of risk to birds at a particular site. The hypothesis is that the greater the number of birds flying at night, in fog and/or rain at rotor height, the greater the potential collision risk is to birds. In the discussion section of this report, the findings of the radar study as they pertain to this risk scenario are examined in detail.

[For an overview of patterns of migration over the Cape Cod, Nantucket Sound, coastal islands, and adjoining Atlantic Ocean, as well as the species involved, the reader is referred to the pioneering radar studies of Nisbet and Drury (1967), and the literature reviewed by Veit and Petersen (1993) and Kerlinger and Hatch (2001), as well as other references texts on bird migration in eastern Massachusetts. With respect to overall migration patterns and behavior the reader is referred to general texts on bird migration such as Kerlinger 1995, Kerlinger and Moore 1989, Able 1999 (especially see chapter by J. Baird on Blackpoll Warbler migration in coastal Massachusetts), and other general texts and reviews.]

2.0 STUDY AREA AND METHODS

In order to gather data on the migratory behavior and movements of different species into, out of, and through Nantucket Sound, avian radar studies were conducted during two different times of year (spring and fall) at two separate sites (Figure 1). The dates of radar observations were determined to be those times when the birds that have been demonstrated to be most susceptible to colliding with structures (Avery et. al. 1980, Shire et al. 2000) would be present in the largest numbers. Those species are primarily night migrating songbirds, although the spring and fall periods selected also include the period when larger numbers of shorebirds and other species are present along the coast of Massachusetts (Veit and Petersen 1993). The timing of the study was also selected based on input from Ian Nisbet to the USACE.

Figure 1: Locations of Nantucket Sound Radar Survey Sites

2.1 Radar Locations

The spring radar study was conducted on Horseshoe Shoal in Nantucket Sound from May 8 through June 7, 2002, the peak migration period for most night migrating songbirds and shorebirds. The radar system, a Mobile Avian Radar System (MARS), provided by Geo-Marine, Inc., was located on the *Amelia Mary*, a 64-foot jack-up barge operated by Coady Brothers Marine Services. The barge was located on the southern end of the proposed wind park site (approximately latitude 41^0 28.167”N, longitude -$70^0$20.771”W) and was lifted about 15-feet (4.6 m) above mean sea level (Figure 2). The radar system sat approximately 8 feet (2.4m) on top of the barge so that targets were tracked above approximately 23 feet above mean sea level.

The fall radar study was a land-based study, conducted on the northeast corner of Cape Poge, Chappaquiddick Island, on Martha’s Vineyard (Figure 3) from September 3 through September 30, 2002. These dates correspond to the peak migration period for most night migrating songbirds, terns and shorebirds (Veit and Petersen 1993). The MARS system was located approximately 7 miles (11.2 km) southwest of the spring survey site (approximately latitude $41^0$25.212”N, longitude -$70^0$27.138”W) on a bluff approximately 28 feet (8.5 m) above mean sea level. The radar system sat approximately 8 feet (2.4m) on top of the bluff so that targets were tracked above approximately 36 feet above mean sea level. The survey site looked north across Nantucket Sound from the west.

Figure 2: MARS Study Site: Spring on the Amelia Mary

Figure 3: MARS Study Site: Fall on Cape Poge

2.2 Methodology

Geo-Marine used their MARS system to collect data on the movement of birds in the area for the two migration periods. The MARS system is a trailer-mounted, self-contained, radar system designed to survey bird movements. This system uses two standard marine radars in different configurations for detecting birds. A radar beam forms a wedge (roughly cone shaped) with its point at the radar, but no targets are tracked in the zone where pulse and echo overlap so the rotating radar receives echos from a somewhat donut-shaped volume. The first MARS radar is called a TracScan, a commercial marine S-band radar (Furuno model FR-1420 transmitting 30 kilowatts (kW) at a frequency of 3040 MHz (9.8 cm wavelength)). This radar scans horizontally at 24 rpm, making one full rotation of 360 degrees every 2.5 seconds (Figure 4). The TracScan data were used to determine target position (range and bearing), speed, and flight direction out to 4 nautical miles (7.4 km). The 9-ft (2.7 m) long “bar” antenna focuses the signals into a fan-shaped beam, which is 3 degrees wide in the scanning plane and extends 12.5 degrees above and below the scanning plane. The antenna mount was shimmed to provide another 3 degrees of elevation; in operation, the fan beam extended 15.5 degrees above the horizon, and 9.5 degrees below the horizon, see Figure 4. The TracScan beam hit the surface of the water after 188 feet in the Spring and 295 feet away from the radar in the Fall.

The second radar is called a VerCat, a commercial marine X-band radar (Furuno model FR-1525, transmitting 25 kW at a frequency of 9410 MHz (3.2cm wavelength)). This radar scans in a vertical plane, from the western horizon, to the sky, to the eastern horizon, to the ground, and so forth. The VerCat scans at 24 rpm, making one full rotation of 360 degrees every 2.5 seconds (Figure 5). The 8-ft long “bar” antenna focuses the signals into a fan-shaped beam, which is 1 degree wide in the scanning plane and extends 10 degrees to either side of the scanning plane, see Figure 5. The VerCat data were used to determine target altitudes for birds flying as high as 9,000 feet above mean sea level through the arc of radar energy. As previously discussed, given the design of the VerCat scanner unit, targets could be measured starting at approximately 23 feet above mean sea level for the spring survey and approximately 36 feet above mean sea level for the fall survey. The VerCat is sensitive to rain, so it was not possible to determine altitude of birds during periods of moderate to heavy rain. Data on altitude were not determined during these weather conditions. Full detail on the MARS radar system used in the spring and fall radar studies is included in Appendix 5.7-J.

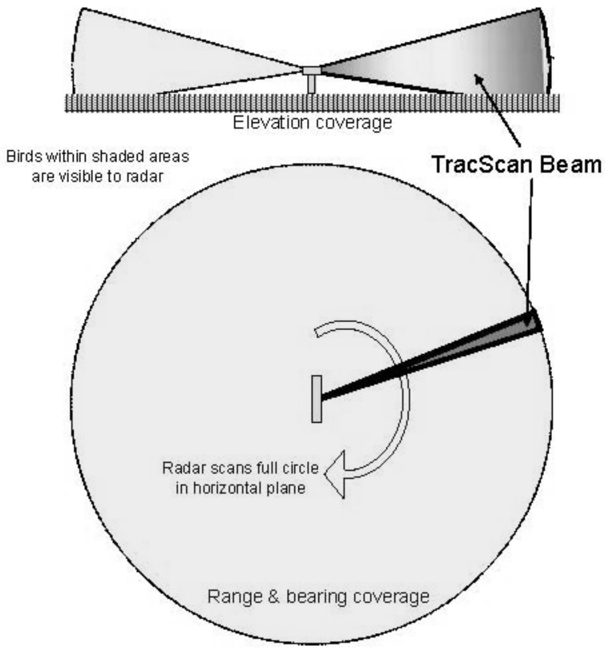


Figure 4. TracScan Coverage Pattern.

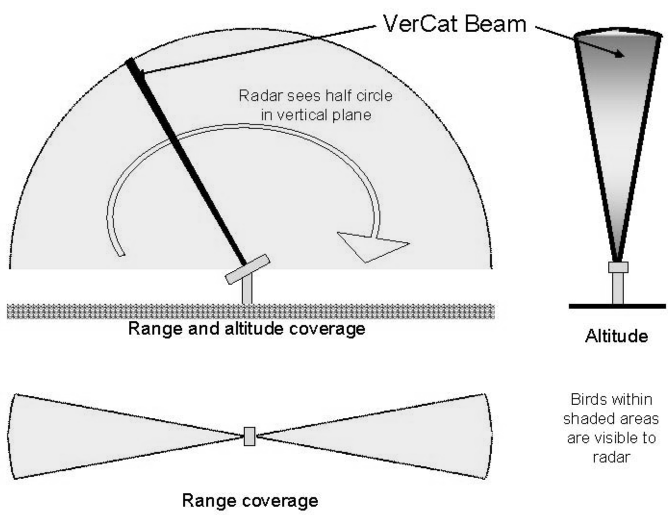


Figure 5. VerCat Coverage Pattern.

2.2.1 Data Compilation

The information provided in this section has been summarized from the GeoMarine Radar Report which appears as Appendix 5.7-J.

Radar Sessions

GeoMarine Inc. takes the radar returns during the listening period and processes them through a specialized high-resolution radar capture card. This card provides radar resolution at least 256 times that of typical commercial radars. GMI-proprietary MARS software processes this high-resolution data to generate dynamic maps of clutter, identify and exploit the small differences between clutter and bird targets, and archive the detections for post-study analysis. All this occurs in real-time, that is, in less time than it takes to complete one full scan of the radar. Data associated with bird targets are written to a Microsoft Access database which can be queried during post-study processing.

VerCat Radar Data

VerCat data from the vertical-scanning radar were used to determine altitudinal distribution of birds passing through the study area. The VerCat radar was calibrated to detect birds out to 0.75 nautical mile east and west of the radar sites and up to 9,000 ft above ground level (in this case, above ground level is approximately the same as above sea level). Many of the indices in the VerCat database were of geometric measurements or calculations of each target identified. The primary data obtained from VerCat were the identification number, date and time, distance east or west of the radar, altitude, and target type. Target types include small birds, medium-sized birds, large birds, flocks of birds, and non-bird targets, such as watercraft or aircraft. For more information please refer to Appendix 5.7-J.

TracScan Radar Data

TracScan radar data were collected using the conventionally-configured, horizontal-scanning radar system. The TracScan radar was set to detect birds out to 4 nautical miles (7.4 km). These bird tracks were used to calculate speed and direction of movement. Birds identified by the TracScan radar were classified into two categories based upon target speed, target intensity, and target shape: slow-moving birds (sometimes foraging birds) and fast-moving birds (moving >27 knots). Because a bird's track results from its flight speed and direction through the air, in combination with the speed and direction of the wind, it is possible for individual birds to be classified in different categories on different days, and for birds' headings to differ greatly from their tracks. The slow speeds of insects, in comparison to birds, permits those organisms to be filtered from the database (Williams et al, 2001). Watercraft and aircraft were also identified in the TracScan data and eliminated from the database. For more information please refer to Appendix 5.7-J.

Weather Data

Weather data were collected and downloaded from Weather Underground for both the spring and fall radar study periods (www.wunderground.com). The weather station located at the Martha's Vineyard Airport, Vineyard Haven, MA was used due to its proximity to both radar locations.

3.0 RESULTS

3.1 Summary of Radar Observations By Season, Day, and Weather Conditions

During spring and fall 2002, a total of 1,837 hours of radar observation data were collected with the TracScan and VerCat radars (Tables 1 and 2). During spring, both radars were operated for a total of 952 hours and during fall they were operated for a total of 885 hours. TracScan and VerCat radars were operated simultaneously throughout much of the study period, although there were times when one of the two was not operating. Thus, the total time when one or the other radar was operating was roughly one-half of the 1,837 hours or 918.5 hours. VerCat observations were conducted on 20.6 of 31 days during spring between May 8 and June 7, 2002 and on 19.0 of 28 days during fall between September 3 and September 30, 2002. TracScan observations were conducted on 19.0 of the 31 days during the spring field study and on 17.9 of the 28 days during the fall study. Simultaneous hours of operations by these radars accounts for the fact that an average of about 31.0 hours of radar observations were made per day (during the 59 days of observations in spring and fall together). This averages to about 15.5 hours per day per radar during spring and fall.

Observations were made during clear, rainy, and foggy conditions during both seasons (Tables 1 and 2). Attachment 1 (TracScan) and Attachment 2 (VerCat) provide the total number of hours of TracScan and VerCat radar observations during clear, rainy, and foggy weather on a daily and nightly basis for the spring and fall study periods. During spring and fall, a majority of observations were conducted during clear conditions. This corresponds roughly to the amount of time that was clear during the entire study periods. During spring, TracScan data under rainy and foggy (not clear) conditions during the day and night accounted for 27.4% of the total radar time and VerCat data under rainy and foggy (not clear) conditions during the day and night accounted for 25.3% of the total radar time. During fall, TracScan and VerCat data under rainy and foggy (not clear) conditions during day and night accounted for 24.7% and 25.0% of the total radar time, respectively. The similarities in these percentages are related to the fact that the radars were used simultaneously.

TracScan observations totaled 886 hours in spring and fall for an average of 15 hours per day. VerCat observations totaled 951 hours in spring and fall for an average of 16 hours per day. Thus, combined radar observations were done during about three-quarters of the 24 hour (day and night) period. Fewer radar observations were made at night during both spring and fall (Table 1 and 2), in part because there are fewer hours of darkness and because the technical aspects of radar operations during darkness are more difficult than in daytime. During spring, 32.7% of observations were made at night and during fall, the corresponding percentage was 41.6%. A breakdown of radar observation hours with each of the radars at night and day during times of rain, fog, rain and fog, and clear conditions is provided in Tables 1 and 2.

Table 1: Summary of hours of observations of the TracScan and VerCat radars in clear, rainy, and foggy weather during spring

	TracScan Radar					VerCat Radar				
	Clear	Rain	Fog	Fog and Rain	Total	Clear	Rain	Fog	Fog and Rain	Total
Day	240	26	18	27	311	267	8	24	31	330
Night	92	15	14	25	146	103	14	21	27	165
Total	332	41	32	52	457	370	22	45	58	495
	Day - Clear = 77.2% Rain = 8.3% Fog = 5.8% Fog and Rain = 8.7%					Day - Clear = 80.9% Rain = 2.4% Fog = 7.3% Fog and Rain = 9.4%				
	Night - Clear = 63.0% Rain = 10.3% Fog = 9.6% Fog and Rain = 17.1%					Night - Clear = 62.4% Rain = 8.5% Fog = 12.7% Fog and Rain = 16.4%				
	Total - Clear =72.6% Non-Clear = 27.4%					Total - Clear =74.7% Non-Clear = 25.3%				

Notes: These numbers are based on 20.6 of 31 days in the field (VerCat) and 19.0 of 31 days in the field (TracScan); May 8-June 7, 2002.

Table 2: Summary of hours of observations of the TracScan and VerCat radars in clear, rainy, and foggy weather during fall

	TracScan Radar					VerCat Radar				
	Clear	Rain	Fog	Fog and Rain	Total	Clear	Rain	Fog	Fog and Rain	Total
Day	198	28	8	18	252	206	29	11	19	265
Night	125	12	18	22	177	136	12	25	18	191
Total	323	40	26	40	429	342	41	36	37	456
	Day - Clear = 78.6% Rain = 11.1% Fog = 3.2% Fog and Rain = 7.1%					Day - Clear = 77.7% Rain = 10.9% Fog = 4.2% Fog and Rain = 7.2%				
	Night - Clear = 70.6% Rain = 6.8% Fog = 10.2% Fog and Rain = 12.4%					Night - Clear = 71.2% Rain = 6.3% Fog = 13.1% Fog and Rain = 9.4%				
	Total - Clear =75.3% Non-Clear = 24.7%					Total - Clear =75% Non-Clear = 25%				

Notes: These numbers are based on 19.0 of 28 days in the field (VerCat) and 17.9 of 28 days in the field (TracScan); September 3 – 30, 2002.

3.2 Summary of Bird Targets Observed Via TracScan Radar

During spring and fall, the TracScan radar registered approximately one million targets (1,052,761) flying within about 4 nautical miles (7.4 km) of the study sites (Table 3). Slow tracks outnumbered fast tracks during both spring and fall and the differences were greatest during night hours suggesting a preponderance of night migrating song and other small birds (including some small shorebirds). Not all of the slow tracks were migrating birds. The slow tracks were also birds foraging over the water at slow speeds. The fast tracks were likely to be caused by migrating shorebirds, shorebirds making shorter distance flights, and waterfowl (both migrating and those making shorter flights), as well as a few loons and other birds that have faster airspeeds than songbirds. Because the tracks included many non-migrating birds, the numbers of migrants involved is a subset of the totals provided in Table 3. The number of bird tracks recorded per hour (Table 3) is roughly equal to birds tracked within the 8 nautical mile (14.8 km) area within which the TracScan radar registered birds (out to about a 4 nautical miles [7.4 km] from the radar).

Table 3: Summary of TracScan radar tracks registered at the two Nantucket Sound study sites during spring and fall 2002.

	Spring				Fall			
	Spring Day	Spring Night	Total	Tracks Per Hour	Fall day	Fall Night	Total	Tracks Per Hour
Slow Tracks	212,045	90,931	302,976 (76.2%)	663.0	174,113	268,639	442,752 (67.6%)	1,032.0
Fast Tracks	70,302	24,196	94,498 (23.8%)	206.8	128,861	83,674	212,535 (32.4%)	495.4
Total	282,347 (71.0%)	115,127 (29.0%)	397,474	870.0	302,974 (46.2%)	352,313 (53.8%)	655,287	1,527.5

Notes: For an explanation of slow and fast tracks, see associated text sections. Also provided are tracks per hour of front.

The passage rates in Table 4, below have been recalculated as numbers of radar tracks per hour per kilometer of front to provide a metric that allows comparison with other migration studies. The rates for slow and fast birds, as well as night and day flying birds, are provided in Table 4. In spring, the avian traffic rate (number of tracks which is roughly the number of birds or flocks) overall averaged slightly less than 60 birds per kilometer of front per hour and in fall the traffic rate was about 103 birds per kilometer of front per hour. Slow tracks (mostly small songbird migrants and foraging birds) outnumbered fast tracks (waterfowl, loons, cormorants, shorebird flocks, etc.) by a ratio of more than three to one in spring and more than two to one in fall. The overall traffic rate in spring was similar between day and night when fast and slow birds are combined. Evaluating fast and slow targets separately shows that there were more slow targets than fast targets in both daytime and night in the spring. During fall, there was little difference between passage rate of fast vs. slow targets in daytime, although at night there were three times more slow targets than fast targets. The rate for slow birds in fall at night was more than twice the daytime rate, whereas the rate for fast birds in the fall was fairly similar between day and night. In the spring these rates hardly differed. The overall finding that there were more slow flying targets tracked at night in both seasons than fast targets, could be explained by the prevalence of migrating songbirds in the night sky.

Table 4: Summary of numbers of radar targets/birds observed per kilometer of front per hour during spring and fall, as well as during day and night.

	Spring Day	Spring Night	Total	Fall Day	Fall Night	Total
Slow	46.1	42.1	44.8	46.7	102.5	69.7
Fast	15.3	11.2	14.0	34.6	31.9	33.5
Total	61.3	53.3	58.8	81.2	134.5	103.2

Notes: The rates reported are calculated from Tables 1, 2, and 3.
Targets/birds per km of front = (overall numbers of birds tracked/ number of hours tracked)/(range of radar x 2)

3.3 Weather and Migration Passage Rate – TracScan Radar

Birds flew during clear, rainy, and foggy conditions. The percentage of time when TracScan radar was operating during which there was rain and/or fog ranged from 21.4% for fall days to 37.0% during spring nights (Table 5). Thus, fog and rain accounted for roughly one-fifth to one-third of all radar operation time. The numbers of birds tracked with the TracScan radar with different weather conditions varied with season and time of day. The absolute and relative numbers of birds flying during low visibility conditions involving rain and/or fog are summarized in Table 5. For small/slow bird targets (songbirds primarily) the percentage flying during these conditions ranged between 12.1% of birds tracked during daytime fall measurements and 41.0% of birds tracked during nighttime spring measurements. For large/fast bird targets (primarily waterbirds and shorebirds), the percentage flying during these conditions ranged between 10.3% of birds tracked during daytime fall measurements and 46.9% of birds tracked during nighttime spring measurements. The percentages of radar tracks of birds registered during fog and rain (combined) varied greatly and seemed to roughly track the amount of time the radar operated during fog and rain. Based on the amount of radar time, the percentage of small/slow moving bird targets tracked during daytime in fall should have been about twice as great. Other differences were not as great, so firm conclusions are not warranted.

Table 5: Summary of the percentages of TracScan radar operation time, along with the numbers and percentage of small/slow targets and larger/fast targets tracked on radar during rain and/or fog during spring and fall migration at different times of the day over Nantucket Sound.

	Spring			Fall		
	Radar	Small/Slow	Large/Fast	Radar	Small/Slow	Large/Fast
Day	22.8%	39,317 (18.5%)	14,639 (20.8%)	21.4%	21,002 (12.1%)	13,242 (10.3%)
Night	37.0%	37,252 (41.0%)	11,338 (46.9%)	29.4%	75,054 (27.9%)	28,195 (33.7%)

Notes: Small/slow targets are primarily songbirds and larger/fast targets are primarily waterbirds and shorebirds. The percentages represent the amount of time during which the TracScan was in operation during rain and, or fog, and the number and percentages of birds (small and large) that were tracked during fog and rain.

3.4 Flight Direction

Flight direction during both spring and fall varied greatly among individuals and groups of birds. Vector diagrams (circular histograms) were constructed to summarize the directional movement of slow-moving and fast-moving avian targets for both spring and fall, both during clear and unclear (foggy and rainy) weather (Attachment 5).

During spring, fast flying birds during both day and night, in both clear and unclear weather had tracks that were well oriented to the northeast. There was some scatter, but the predominant vector was clearly to the northeast, with the next strongest vector being toward the east. The mean direction was estimated to be toward about 55-65 degrees (slightly east of northeast). These observations were from the southern edge of the Cape Wind project site and had a pronounced axis. It is likely that this well oriented movement mostly includes migrants.

On May 20, 2002, a substantial migratory flight of White-winged Scoters was both tracked on radar and visually identified. Their general direction was to the northeast, roughly parallel to the coastline. This is the predominant direction of most spring migrating waterbirds that are flying. However, some species like Common Loons and some others do migrate northward and northwestward toward nesting areas inland.

Flight direction of slow flying targets during day and night in spring, in clear and unclear weather was far less oriented than the tracks of fast flying migrants. There seems to be a bimodal distribution, to the northwest and southeast among these tracks, although there is a great deal of variation. Birds basically moved in all directions with slightly greater numbers flying to the northwest and southeast. These slow flying targets include songbirds migrating over the Sound, as well as slow flying birds such as gulls foraging.

During the fall migration period, flight direction was highly scattered, with some directional trends evident. The explanation for this variability is suggestive of combinations of migrating birds and birds making local movements to and from the Cape Poge area. Visual observations during daytime revealed large numbers of a variety of birds flying out over the water and over the shoreline. Among fast flying migrants, during day and night, there seemed to be a northeast to southwest axis, with the northeast vector being slightly stronger. There was also an indication that many birds moved toward the southeast. Thus, the data are not clear with respect to directional tendencies of migrants. Slow moving targets during day and night, in both clear and unclear conditions were mostly oriented toward the southeast. This was particularly clear for night movements in unclear weather. During clear weather there was a bimodal trend with peak directional activity being to the northeast and southeast. Daytime movements of small birds were much more variable, although the strongest vector was to the southeast.

3.5 Vercat Radar Observations – Altitude of Flight

During spring and fall study periods, a total of 491,306 avian radar targets (153,266 (31.2%) in spring; 338,040 (68.8%) in fall) were registered using VerCat radar (Table 6). There were slightly more targets detected at night

(55%) than during daytime (45%). The analyses of altitude that follow rely on the data provided in Attachment 3. The types of birds involved include migrants and nonmigrants, as well as small and large targets (birds), although a majority of the birds tracked at night were likely to be migrants. A summary of the different size birds within the different elevational strata classes registered via VerCat radar is provided in Attachments 3 and 4.

Table 6: Numbers of avian tracks registered by VerCat radar over two Nantucket Sound study sites during spring and fall study periods.

	Spring	Fall	Total
Day	70,382 (45.9%)	150,677 (44.6%)	221,059 (45%)
Night	82,884 (54.1%)	187,363 (55.4%)	270,247 (55%)
Total	153,266 (31.2%)	338,040 (68.8%)	491,309

Notes: Spring study period: May 8 – June 7, 2002; fall study period: September 3 – September 30, 2002.

For ease of analysis and assessment of potential risk to birds flying in the study area, radar targets were sorted into three height categories (Attachment 3 and 4). The 75-417 foot asl height band corresponds roughly to the rotor swept height zone (the area in which the rotor turns). Overall, 26.0% of all targets (127,697) in both spring and fall during all times of day were tracked by VerCat within the rotor swept zone and very few were tracked below that zone. During spring and fall, 16.5% of targets were recorded in this zone at night and 37.6% were in this zone during daytime (Table 7). Of all small targets tracked within the rotor swept zone, 15.3% were tracked at night and 32.9% were tracked during the daytime (Table 7). Of all medium targets tracked within the rotor swept zone, 19.2% were tracked at night and 44.1% were tracked during the daytime (Table 7). Of all large targets tracked within the rotor swept zone, 28.5% were tracked at night and 60.2% were tracked during the daytime (Table 7). It is important to note that during aerial and boat surveys (and presumably during the radar observations), the majority of birds (mostly seabirds and other waterbirds - loons, terns, etc.) were observed on the water or flying at altitudes below the lowest range of the radar. Therefore, there was a large percentage of low flying birds below the range of the rotors that were probably not tracked by the radar. For this reason, the percentages of birds tracked within the rotor swept zone during the radar surveys (Table 7) may overstate the total percentage of birds flying in this zone since it does not include a large number of birds flying below rotor height. However, these percentages do provide an estimate of the birds flying within rotor height that were within tracking range of the radar. The actual percentages of birds in the Project Area flying within the rotor height are likely to be much smaller.

Table 7: The percentages of targets observed in the rotor swept zone during both spring and fall radar surveys. Data collected using VerCat radar.

Overall	Overall Targets		Small Targets		Medium Targets		Large Targets	
Total	Day	Night	Day	Night	Day	Night	Day	Night
26.0% (127,697/ 491,306)	37.6% (83,083/ 221,059)	16.5% (44,614/ 270,247)	32.9% (52,180/ 158,675)	15.3% (32,570/ 213,019)	44.1% (18,839/ 42,766)	19.2% (9,361/ 48,827)	60.2% (7,359/ 12,228)	28.5% (1,806/ 6,326)

Notes: The rotor swept zone is between approximately 75 and 417 foot asl. The radar could not track low flying birds flying below approximately 35 asl.

As presented in Table 8, during spring daytime observations, nearly two-thirds (65.7%) of all VerCat observations were within the 75-417 foot rotor height band, whereas during spring nighttime observations, 30% of the VerCat observations were within the rotor height zone. This suggests that fewer birds fly at night in the rotor swept zone. For small targets in the spring, (mostly songbirds) 41.2% flew within this height band during daytime and 21.8% flew within this band during the night. This seems to indicate that during the night, small birds generally flew at higher elevations over the water. For medium and large targets in the spring, 20.3% flew within this height band during daytime and 7.3% flew within this band during the night.

Table 8: The percentages of targets observed in the rotor swept zone during spring radar surveys. Data collected using Vercat radar

Spring Totals	Spring Targets		Spring Small Targets		Spring Medium Targets		Spring Large Targets	
Total	Day	Night	Day	Night	Day	Night	Day	Night
46.4% (71,106/ 153,266)	65.7% (46,268/ 70,382)	30.0% (44,838/ 82,884)	41.2% (29,024/ 70,382)	21.8% (18,046/ 82,884)	13.8% (9,735/ 70,382)	5.8% (4,834/ 82,884)	6.5% (4,587/ 70,382)	1.5% (1,244/ 82,884)

As presented in Table 9, during fall daytime observations, 24.4% of radar tracked objects flew between 75-417 feet asl, whereas during fall nighttime observations, only 10.6% flew within this altitudinal band. Small birds flying within this altitudinal band in the fall included 15.4% during daytime and 7.7% during the night. For medium and large targets in the fall, 7.8% flew within the rotor swept zone during daytime and 2.7% flew within this zone during the night. It would seem that during both spring and fall, fewer birds fly at low elevations during night than in daytime and fewer birds fly within the rotor swept zone during night than in daytime.

Table 9: The percentages of targets observed in the rotor swept zone during fall radar surveys. Data collected using VerCat radar.

Fall Totals	Fall Birds		Fall Small Targets		Fall Medium Targets		Fall Large Targets	
Total	Day	Night	Day	Night	Day	Night	Day	Night
16.7% (56,591/ 338,040)	24.4% (36,815/ 150,677)	10.6% (19,776/ 187,363)	15.4% (23,156/ 150,677)	7.7% (14,461/ 187,363)	6.0% (9,104/ 150,677)	2.4% (4,527/ 187,363)	1.8% (2,772/ 150,677)	0.30% (5,621/ 187,363)

As presented in Table 10, during the spring, 48.9% of all radar tracks were above 418 feet and during the fall, 83.1% of all radar tracks were above this height range. During the spring, 27% of radar tracks were above 418 feet in the daytime and 67.5% were above 418 feet at night. During the fall, 75.2% of radar tracks were above 418 feet in the daytime and 89.4% were above this altitude during night.

Table 10: The percentages of targets observed above the rotor swept zone during spring and fall radar surveys. Data collected using VerCat radar.

Spring			Fall		
Day	Night	Total	Day	Night	Total
27% (18,977/ 70,382)	67.5% (55,975/ 82,884)	48.9% (74,952/ 153,266)	75.2% (113,354/ 150,677)	89.4% (167,487/ 187,363)	83.1% (280,841/ 338,040)

4.0 DISCUSSION

The present radar study adds significantly to our knowledge of bird migration and other movements over Nantucket Sound during spring and fall. Previous studies, such as those by Nisbet (1963, 1970), Nisbet and Drury (1969), and Drury and Nisbet (1964) used radar, moon watching, and other methods to examine migration behavior at night during the fall. These studies focused on orientation behavior of migrants in relation to cloud cover and fog, as well as altitude of flight. They were also mostly focused on Cape Cod, as well as the waters surrounding the Cape. The radar used in these previous studies actually measured migration over much of Nantucket Sound, although the radar station was in South Truro, more than 30 miles north of Horseshoe Shoal.

The TracScan and VerCat radars used in this study were particularly useful for monitoring the number and behavior of birds flying during day and night over Nantucket Sound. These radars provided a more fine-scaled view of bird movements than the radars used by previous researchers. In addition, the information gathered in this study was obtained during fall and spring periods, both day and night. Previous studies focused only on night migrants during fall migration. The difference between the radars used in this study and those used for previous studies (listed in the previous paragraph) is the ability of modern radars to track birds more closely and measure altitude down to within about 20 feet of the water. Nisbet (1963) was unable to measure altitude below about 600 feet, although he did state that some birds flew at those low elevations.

The TracScan provided a measure of the traffic rate of migrating and foraging birds, along with flight direction near the two radar locations. Also, the TracScan provided estimates of the relative numbers of birds flying during different weather conditions, including those conditions that are believed to be associated with large-scale collisions of night migrating songbirds with communication towers and other brightly lit structures. The VerCat provided a vertical profile of migrants from the top of the radar upwards for several thousand feet asl. These radars were particularly important at night when nocturnally migrating and foraging birds were active.

Of the two radar locations used in this study, the location at the southern edge of Horseshoe Shoal during spring, provided a more representative sample of bird activity at the Project Site and in nearby waters. With a range of about 4 nautical miles, the radar detected birds over much of the Cape Winds project area. The spring study yielded detailed information regarding spring migration at the proposed wind park site, as well as information regarding local or foraging movements of birds in that area. The radar data from spring, however does not include landbirds making short forays over the water, as did the study from Cape Poge in fall. From Cape Poge, the radar detected birds in the southwestern portion of the Cape Winds project area, as well as birds in waters to the south of Horseshoe Shoal and over Martha's Vineyard. Virtually all radar targets that were determined to be birds at the spring radar location were likely to be a subset of the migrants or foraging waterbirds that are normally found in the vicinity of Horseshoe Shoal and the Cape Wind Project Site during that season.

The fall radar location on Cape Poge was somewhat removed from the Horseshoe Shoal Project Site, but birds flying toward or from the site were definitely a portion of the birds tracked. This would include migrants and foraging birds, in addition to the more typically land-based species. There is likely to be a bias toward tracking land-based and shorebirds at Cape Poge because many birds flew close to and over the shore near the radar site. Although these birds can be found offshore at the proposed wind park site, they would be more numerous near shore and on land so numbers of these types of birds tracked by radar in the fall are likely to be higher than what would be found offshore at the proposed wind park site. Some of these land-based or shore based species include gulls and terns, soaring in the updrafts of the bluffs near the radar, the same species making short distance foraging flights around Cape Poge and the nearby waters. In addition, waterbirds (cormorants, ducks, etc.) making foraging flights nearby, and lesser numbers of landbirds (tree swallows, ospreys, etc.) simply flying in the vicinity of the radar would be included. These birds were likely tracked on radar repeatedly as they flew on successive days and more than once on the same day. Activity along shorelines can be intense and almost always much greater than activity miles out over the water.

Passage/Traffic Rates. The TracScan revealed that during May/June about one million bird targets (hereafter referred to as birds) flew over the Cape Wind Project Area at Horseshoe Shoal during the two study periods. This estimate assumes 58.8 birds per kilometer of front per hour across a front of nearly 22.7 km (about the diameter of the wind turbine area). During September, the number of birds likely to pass through this area is estimated to be about 1.7 million (assuming 103 birds per kilometer of front per hour). These numbers include both daytime and nighttime observations and likely include many birds (especially those that are foraging) that are tracked on multiple occasions. With respect to night migrating songbirds and similar species (small objects tracked at night), it is estimated that during May/June about 315,000 birds pass (assuming 8 hours of darkness), whereas in September about 577,000 pass (assuming 11 hours of darkness). These estimates are subsets of the overall numbers of birds and migrants that fly over the Cape Wind Project Area. Risk would not likely be equal for all birds because birds passing through the center of the 22.7 km diameter circle would pass over or through more wind turbines than birds passing along the edges of this area. The numbers of birds actually passing during the entire spring and fall migration seasons is undoubtedly larger, but it is difficult to extrapolate to these numbers because the numbers of migrants and foraging birds changes during the season. However, by studying the area during the peak of spring and fall activity for night migrating song and shore birds, it is likely that the rates reported in this study are higher than an overall rate for the seasons. Absolute numbers of migrants passing through the study areas are certainly larger than those numbers reported herein, even though the rate of migration earlier and later in the spring and fall migration seasons are likely to be smaller than the peak season studied.

Although the pioneering radar studies of Nisbet (1963) and Drury and Nisbet (1964) did not determine quantitative estimates of migration traffic or passage rates, they do provide a few hints regarding numbers of migrating bird numbers (Nisbet and Drury 1967). Their figures and text do permit qualitative comparisons with the passage rates determined in this study. The estimates from the Cape Wind radar studies do not include low flying birds, so the Cape Wind radar traffic rates are primarily nonwaterbirds, which are the birds that fly the lowest to the water. It should be noted that the Drury and Nisbet, and Nisbet studies could not measure birds close to the water either, so the qualitative comparisons are legitimate. Apparently, the radar studies from the 1960s made little attempt to examine traffic rates, perhaps because the radars used were not comparable to modern radars. However, some of the radar PPI (Plan Position Indicator) photographs in Drury and Nisbet (1964) show relatively greater numbers of migrants over Cape Cod and to the north of Cape Cod as opposed to south of Cape Cod where the project area is located. There is also some indication in Drury and Nisbet (1964) and Nisbet and Drury (1967), based on direction of flight and where most radar targets were in relation to the ocean, that fewer migrants fly offshore as opposed to onshore. Because the direction of fall migration is primarily to the southwest (about 210-240 degrees), it appears that many night migrants avoid flying out over the Atlantic Ocean or Nantucket Sound. Nisbet and Drury (1967) suggested that fewer night migrating songbirds flew out over the Atlantic Ocean during fall than were seen farther inland. They stated that migration was much more dense to the northwest of Boston and that migrants were “much more sparsely” found to the southeast of that city. In spring, the Nisbet and Drury radar data showed “much smaller numbers southeast of Boston,” as opposed to inland from Boston. This again suggests that fewer songbird migrants fly out over the Atlantic or other oceans than fly overland, and that these birds seem to prefer migrating overland (reviewed in Berthold 2001). Blackpoll Warblers are the songbird species most represented among songbirds that fly long distance from the New England shoreline toward the southeast and South America (Baird 1999, Nisbet and Drury 1967). Other songbird species leave the New England shoreline in good numbers, although they may not make the long journey to South America. Instead, many are likely to come back to shore and the radar data from both Nantucket Shoal and Cape Poge show small, slow moving targets flying toward the mainland. Ralph (1978) estimated that as many as 10% of songbirds migrating along the coast of eastern North America fly out over the ocean and die. A vast majority of these birds are immature and inexperienced birds that are “less competent and less experienced” that “are eliminated from the population” (Nisbet and Drury 1967). This may explain the non-Blackpoll Warbler songbird species that are observed at sea and at islands in the Atlantic Ocean. Many individuals of these other species likely perish at sea.

The earlier radar report also mentions smaller movements to the southeast at night, as well as movements in many directions. It is curious that Drury and Nisbet (1964) do not provide any overall analysis regarding direction of night migration. Instead, Drury and Nisbet divided their data into categories, based on a post-hoc analysis of the directions birds were flying. In other words, they qualitatively made decisions and divided the birds into directional categories based on their flight directions. They found “six prime directions” in autumn and three in spring (Nisbet and Drury 1967). They determined that the majority of birds migrated from northeast to southwest in the autumn, presumably with lesser migrations being in other directions. “Movements towards the southeast, east, and northeast were observed regularly, but are not analyzed in this paper” (Drury and Nisbet 1964). For this reason, direct quantitative comparisons between the present study and the earlier radar studies are not possible. It is interesting that in both studies, there was a large degree of variation in the directional tendencies of birds aloft, suggesting that the two data sets show similar flight behaviors of migrants and other birds.

Gauthreaux (1980) and Able (1973) in their classic radar and ceilometer studies from Louisiana, Georgia, and South Carolina show passage rates of night migrating birds in the thousands to tens of thousands of birds per hour per kilometer of front (Table 11). These rates are mostly from sites that are many miles from coastlines or other areas that serve as migratory stopover sites or where birds are known to concentrate in vast numbers. In his 1980 review paper, Gauthreaux refers to passage rates below 4,500 birds per hour per nautical mile (about 2,400 per kilometer) of front as “light migration.” Migration was considered “heavy” when more than 2,500 birds per hour per kilometer of front were registered. Some of the heavy rates reported by Gauthreaux included more than 50,000 birds per hour per kilometer of front, many times the average rate determined for flight over Nantucket Sound during the 2002 radar surveys. Elsewhere, Gauthreaux (1971) reported migration traffic rates of greater than 10,000 birds per kilometer of front per day (rather than per hour) for a study in coastal Louisiana. It would appear that migration traffic rates over Nantucket Sound are not as great as reported from some onshore sites, although rates are not available from many locations because radar studies are scarce and don’t always quantify migration traffic rates.

The bird traffic and migration rates, especially small birds at night, found for Nantucket Sound in spring and fall by the current study are lower than or similar to those found at many sites in the northern United States, including studies from inland Maine, New York State, and North Dakota (Table 11). In those studies, the rates ranged from a few tens of birds per hour per kilometer of front to several hundred. The most likely explanation of the difference between traffic migration rates reported in the studies from the northern and southeastern United States is the difference in source area for migrants. Sites in the north, including the Nantucket Sound study, have a much smaller source area for migrants than those studies in the southeastern United States. Furthermore, there is more land area farther west, from which migrants come during fall migration, as has been documented by more than 30 studies of migration (summarized in Gauthreaux 1980a).

Table 11: Summary of night migration traffic rates per kilometer of migration front per hour for several sites in the United States.

Location of Radar or Ceilometer Study	Traffic Rates (per km of migration front per hr)	
	Spring	Fall
Cape Wind Project Area – Nantucket Sound	53	135
New York (all radar)		
Cape Vincent – 1994	473[1]	N/A
Copenhagen – 1994	280	341
Martinsburg – 1994	N/A	661
Harrisburg – 1998	N/A	135
Wethersfield – 1999/1998	42	175
ME – New England WES – 1994	71	478
Radar (ceilometer)	2.2 (220)	4.7 (470)
VT – Searsburg 1996-1997 – ceilometer (conversion)	1.9 (195)	4.6 (460)
North Dakota – ceilometer (conversion)	5.3 (530)	4.9 (490)
GA, SC, LA – Radar – Weather and Airport Surveillance	100s-10,000s	100s-10,000s
New Orleans, LA – ceilometer (conversion)	55 (5,500)	95 (9,500)
Lake Charles, LA – ceilometer (conversion)	N/A	264 (39,600)
Athens, GA ceilometer (conversion)	57 (8,550)	132 (19,800)

Notes: Measurements from the Cape Wind sites are for all (fast and slow) night migrants (see Table 3 above). Measurements from New York sites are from marine surveillance radar studies (Cooper et al. 1995, Cooper and Mabee 1999). Maine site data is from marine surveillance radar and ceilometer studies (Northrup et al. 1995a, 1995b). Measurements from Vermont and North Dakota are from ceilometer studies (bird per hour of observation; Kerlinger 2000, Avery et. al. 1976). Numbers in parentheses for ceilometer studies are conversions according to Gauthreaux (1980b; ceilometer rate times 100 to equal birds per kilometer of front per hour). References for southeastern United States sites are in text, above.

Another reason lower passage rates of small night migrating birds were detected over Nantucket Sound than in the southeastern United States may be a result of the fact that the bulk of small night migrants are songbirds and most songbird migrants do not migrate out over the Atlantic Ocean for long distances, at least in the northeastern United States (Kerlinger 1995, Baird 1999, Nisbet and Drury 1967). Gauthreaux (1980a) reported the direction of both spring and fall (mostly songbird) migration in the eastern United States, showing that the primary direction of flight keeps most birds over land until they reach the Gulf of Mexico in autumn, which agrees with the radar data from Cape Cod, although at the latter site there is a greater variation in flight direction. The greater variation in flight direction in Nantucket Sound and Cape Cod is likely attributable to the fact that there are waterbirds, gulls, shorebirds, and some other species involved, whereas in the southeastern United States fewer of these birds are present during night migration. . In spring, the direction of night migration in New England keeps a majority of songbirds over land. Of course, winds do blow some landbirds out over the ocean and others choose to fly out over the ocean, including shorebirds and some songbirds (Richardson 1979). Nisbet and Drury (1967) did see what they interpreted as shorebirds arriving from the southeast, which is from the Atlantic Ocean.

Comparing migration traffic rates at sites where there are also estimates of mortality are of heuristic value (Table 12). Studies conducted at the Buffalo Ridge wind power facility of Minnesota, where there are currently about 400 turbines; at Nine Canyons wind power facility in Washington, where there are 37 turbines; and at the Stateline Project in Washington/Oregon, where there are about 400 turbines are the only studies now available for making such comparisons. The migration traffic rates at these sites are not dissimilar to the overall bird passage rates and night migration rates at the two Nantucket Sound radar sites described in this study.

A study conducted at the Buffalo Ridge Wind Power Project site in Minnesota (Hawrot and Hanoski 1997, Johnson et al. 2002) showed that 3.5 million birds migrated over the wind turbine area each year. Despite those large numbers (as well as the large numbers of nesting birds that made local flights in the turbine area), the mortality registered at that site during 4 years of systematic searches was not considered to be biologically significant (Johnson et al. 2002). Rates of fatalities were calculated to be about 1 to 4+ birds per turbine per year when scavenging (carcass removal) and observer efficiency were included. Spring migration rates and corresponding fatalities were lower (Table 12). Similar migration traffic and fatality rates were found at both the Stateline and Nine Canyons sites (Table 12). None of these sites had biologically significant numbers of fatalities.

It should be noted that a large number of birds use Nantucket Sound as a foraging area and those birds were likely counted repeatedly both on the same day and on subsequent days during the fall and spring Cape Wind radar surveys. For example, large numbers of gulls and other waterbirds (scoter, eider, Long-tailed Duck, gannet, loon, etc.) were observed during the spring study. The gulls were in flocks of dozens and often followed squid trawlers. The large numbers of gulls, terns, waterfowl, cormorants, gannets, and other birds that frequent the coast of Martha's Vineyard, were likely counted on multiple occasions. The rates of birds tracked per hour therefore, do not reflect the numbers of migrants that fly through Nantucket Sound or the Project Site.

Table 12: Summary of pre-construction spring migration traffic/passage rates (per kilometer of front per hour) and post-construction spring migration fatality rates at sites where comparisons are available.

Site	Stateline, OR/WA	Buffalo Ridge, MN	Nine Canyon, WA
Number Of Turbines	454	400	37
Passage Rate (targets/km/hr)	50	93	98
Fatality Rate/Turbine	0.075	0.261	0.161
Total Fatalities (spring)	34	104	6

Notes:
1. Also included are the total number of turbines at each site, the migration passage/traffic rate as determined by marine surveillance radar (like a TracScan) and fatality rates per turbine per year.
2. Passage rate is the number of targets per kilometer of migration front per hour
3. Fatality rates were calculated from actual numbers by including empirically determined carcass, scavenging rates, and searcher efficiency rates.
4. Fatalities are the fatality rate (above) multiplied by the number of turbines present.

Height of Flight. To assess the potential for collision risk with the proposed WTGs, the proportion of birds flying within the rotor height zone (75-417 feet asl) was examined. Because less risk has been found for most birds flying during daytime hours, the behavior of night flying birds is more critical to examine when evaluating potential impacts. Erickson et al. (2001) demonstrated that at most newer wind plants, night migrants were more numerous on the fatality lists than were day flying birds, which has since been corroborated for eastern and some western studies (Kerns and Kerlinger 2003, Nicholson 2002, Erickson et al. 2003 [when Horned Larks are excluded]). Daytime migrants make up a small proportion of the birds killed by turbines in many studies, especially in the eastern United States (Erickson et al. 2001, information from recent unpublished studies in West Virginia and Tennessee). Therefore, the following paragraphs focus primarily on birds (mostly songbirds and shorebirds) flying at night over Nantucket Sound. Risk to daytime fliers at sites in the eastern United States is likely to be lower, as has been demonstrated previous studies (Kerns and Kerlinger 2004, Nicholson 2003).

The majority of birds tracked at night are likely to be songbirds and shorebirds because these species migrate primarily at night and are more numerous than other night migrants like waterfowl. Furthermore, some species like cormorants do not migrate at night. During spring, slightly more than 21.8% of all small night targets were flying between 75 and 417 feet asl, whereas during fall only 7.7% of small night targets were in this height zone. It should be noted that any birds flying low over the water (less than approximately 30 feet asl) would be below the rotor swept zone, but would not be detected via radar. This and other radar studies are in agreement. A large majority of night migrants fly at altitudes well above the proposed rotor height (Kerlinger 1995, Kerlinger and Moore 1990, Able 1970, etc.). For songbirds migrating at night, the average height of migration is usually above 1,000 feet asl. Radar studies by Gauthreaux (1972) of migrant songbirds flying over the Gulf of Mexico and southern Louisiana during spring migration showed that fewer than 10% of all migrants flew below about 1,000 feet (305 m) asl and more than 60-70% flew higher than 3,000 feet (914 m) asl. This is also in agreement with the data provided by Nisbet (1963) summarized above.

Migration of shorebirds over the ocean usually occurs at high altitudes, so it is possible that many of the birds observed by the radar at more than 3,000 feet (914 m) asl were shorebirds. Richardson (1979) tracked shorebirds leaving the coast of New Brunswick and Nova Scotia during autumn migration, beginning their 2,000 mile flight to South America. These birds climbed as they left the shoreline and mean daily altitudes were often about 5,000-6,000 feet (1,524 – 1829 m) asl. Richardson (1976) reported migrants arriving in Puerto Rico from over the Atlantic Ocean in autumn flying at 3,000 to 6,000 m (9,842 to 19,685 feet) above the island and ocean on many occasions, descending to lower altitudes during night (1000-2000m; 3280-6560 ft) and flying at higher altitudes during the daytime (3000-4000m; 9840-13120 ft). Nighttime altitudes of migrants over water tend to be somewhat lower, as reported in most of the above studies, but a large majority of migrants still fly in excess of 1,000 feet (305 m) asl. Other studies listed in Richardson (1976) and the Gauthreaux papers cited above are in agreement with these findings.

In general, the migration altitude of seaducks (eiders, scoters, and Long-tailed Ducks) which were present in Nantucket Sound mostly during the spring radar study, occurs primarily at very low altitudes above the water, mostly outside of the radar tracking range and outside of the rotor swept zone. Those seaducks that were tracked by the radar would be tracked as medium or large targets. During the spring, only 7.3% of all medium and large night targets were flying between 75 and 417 feet asl and during the fall, only 2.7% of medium and large night targets were flying in this height zone. In studies by Johnson and Richardson (1982) along the Alaskan Coast of the Beaufort Sea, both scoters and eiders migrated mostly below about 25 m (82 feet) above the waves and 46% were below or equal to about 2 m (6.6 feet) above the waves. This is very similar to the height of scoter migration over the Atlantic along the southern New Jersey coastline (Clay Sutton, personal communication; observations of P. Kerlinger). Migrating seaducks do fly higher over land and very small numbers do so over water; some were noted by Johnson and Richardson flying at more than 250 m (820 feet). Along the Atlantic Coast of New Jersey, where hundreds of thousands of waterbirds migrate each autumn, only a small percentage of seaducks and loons migrate above about 50 feet (15 m) above the waves (P. Kerlinger, personal observations). Cormorants, however, migrated at slightly higher altitudes and a larger percentage of the New Jersey migrants flew above 50 feet than was the case for seaducks and loons (P. Kerlinger, personal observations).

Nisbet (1963) reports that the “most frequent altitude” of night migrants is “between 1,500 and 2,000 feet” asl. Overall, Nisbet’s study is in agreement with the current radar study, although the current study reports more birds at lower altitudes (see Table 7 and Attachment 3). Nisbet reports few night migrants flying below about 600 feet and he believed that “on average, only 10-20% of the echoes were below 600 feet, and that many of these were of non-migrating birds…” This is roughly similar to the findings of the present study. It should further be noted that Nisbet observed birds flying above fog layers, rather than within them. Birds did fly mostly below ceiling (cloud cover), but those cloud covers were very often thousands of feet above the ground/sea. Similar results have been reported in other radar studies, with birds flying below heavy or continuous cloud ceiling (Berthold 2001).

<u>Flight in Fog and Rain</u>. Most birds do not initiate migratory flight in rain or heavy fog (reviewed in Berthold 2001), although birds do fly into such conditions after they are already in flight. Sometimes they will land when rain starts, but over the open ocean or other large body of water like Nantucket Sound, they cannot land. The data reported herein do show that birds were moving in varying numbers in fog and light rain, during both day and night.

The direction of migrants, as reported by Drury and Nisbet (1964) and Nisbet (1963) did not seem to be influenced by fog or cloud cover except on a very few occasions and migrants were well oriented during these conditions (birds were flying above the fog). According to Nisbet (1963), very few migrants were disoriented and “No birds at all were seen migrating on nights when there was steady rain…” although some were present during showers. It is interesting to note that even birds flying into a “squall of rain about one mile wide” did not descend to lower altitudes. Nisbet’s radar observations showed these birds emerge from the squall at the same altitude they entered it.

There have been no large-scale fatality events reported from wind turbines in the United States (Erickson et al. 2001) or Europe, nor have there been such fatality events at unguyed communication towers up to nearly 500 feet in height (review of literature [Kerlinger 2000; Avery et al. 1980, Shire et al. 2000] and recent studies – J. Gehring, presentation to U. S. Fish and Wildlife Service Communication Tower Working Group, February 11, 2004, Arlington, VA). There is, however, ample evidence that large-scale fatalities have been documented at tall, guyed communication towers, almost all in excess of 500-600 feet in height during times when there is fog, low-ceiling, and, or precipitation. (Avery et al. 1980). Furthermore, with the exception of the Altamont Pass in California where there are 5,400 wind turbines, few birds of any kind have been demonstrated to collide with wind turbines (or even tall, guyed communication towers), and the impacts have not been demonstrated to be biologically significant.

For this reason, this discussion focuses primarily on night flying birds, including night migrants. Fewer than one-fifth of all birds tracked during these radar surveys at night in spring and fall were tracked during fog and rain, although the detection of birds with radar during heavy rain (when they are least likely to be flying) is problematic. Some of these birds could, potentially be at risk of colliding with turbines if no avoidance of the turbines is assumed. To assess collision risk to these birds, turbine lighting must be examined.

Night Migration and Attraction To Lights. A key issue regarding night migration of songbirds is the question of FAA obstruction lighting of wind turbine lights and their attractiveness to birds to the turbines during periods of fog, light rain, and low ceiling (cloud cover). The fact that thousands of night migrating birds have been shown to collide with brightly lit structures such as the Washington Monument, tall buildings, water towers, as well as communication towers (Avery et al. 1980) suggests that night flying birds, including migrants, may be at risk of colliding with the WTGs in Nantucket Sound. Avery et al. (1980), Larkin and Frase (1988) and others have determined that with fog, rain, and low-ceiling conditions, communication tower or other lights attract birds to the communication towers or other structures. The diffraction of tower lighting by water droplets tends to brighten a larger area around the tower, within which birds fly in circles. It is at this time that they collide with guy wires.

The key to understanding the potential for collision risk is the type of lighting used and the height of the structure. To date, flashing red lights and red flashing incandescent lights on wind turbines have not been demonstrated to attract night migrating birds. Kerlinger and Kerns (2003) demonstrated that despite the presence of red flashing lights on hundreds of turbines at several sites in the United States (Minnesota, Oregon, Washington, Colorado, Pennsylvania, New York, West Virginia, and Wisconsin) there have been no large-scale fatality events at wind power facilities. These studies showed that the FAA obstruction lighting for wind turbines (L-864 flashing red) is completely different from the types of lights demonstrated by Avery et al. and others to attract night migrating birds to communication towers. Communication towers can have two types of lights, often the L-864 or other red flashing lights, in combination with red, steady burning L-810 lights. It is the steady burning red lights that experts now agree contribute to the attraction to birds (Communication Tower Working Group Meeting, February 11, 2004, Washington, DC, Kerns and Kerlinger 2004). The Cape Wind Project does not propose to use these steady burning red lights on the WTGs, but instead will use only flashing lighting. Because strobes or flashing LED bulbs go to complete darkness, birds do not seem to be attracted. All lights proposed for the Cape Wind Project will be flashing lights set to flash at 20 flashes per minute (the longest off cycle allowed by the FAA) and will utilize strobe or LED bulbs where possible. This strongly suggests that the flashing red lights that will be used for the Cape Wind turbines are not likely to attract night migrating or other birds.

Waterfowl and shorebirds have very rarely collided with wind turbines (Erickson et al. 2001) or with communication towers (Shire et al. 2000). Studies at dozens of wind power sites were summarized by Erickson et al. and only a small percentage of the birds found in these studies were waterfowl or shorebirds. Shire et al. summarized the fatalities at about 50 tower studies and found relatively few waterfowl or shorebirds as compared with night migrating songbirds. They also did not report many raptors, as was the case with wind turbines outside of California (Erickson et al. 2001). Therefore, it appears that shorebirds and waterfowl are not at great risk of colliding with tall structures, even those with standard FAA lighting of the type used for wind turbines and communication towers. Risk to those species flying over Nantucket Sound is likely to be minimal and not ecologically significant.

Virtually all large-scale incidents involving bird collisions with man-made objects involve night migrating songbirds, with some other taxa accounting for a small percentage of fatalities. The reason for most collisions is related to either bright lights or FAA lighting (Avery et al. 2001) as well as tower height. Large-scale mortality events have primarily been noted at communication towers in excess of 500-600 feet with guy wires and multiple sets of lights. At the tall communication towers involved in large-scale mortality events (Avery et al. 1980, Shire et al. 2000), the lighting is very different from that used for wind turbines.

The lack of large scale mortality events (like those at tall communication towers and towers lit by spotlights or sodium vapor type lights) at wind turbines is attributable in part to the lack of guy wires. More importantly, the lights on wind turbines do not seem to attract migrating birds (Johnson et al. 2002 and Kerlinger and Kerns 2003 review of wind turbine fatalities and lights at sites in WV, WI, CO, WA, CA, OR, MN, PA, NY – available at www.nationalwind.org). Wind turbines are typically equipped with a single or pair of blinking light (usually flashing red fixtures on newer turbines) and are not recommended by FAA to have intermediate (at several height levels) steady red lights that are recommended for tall communication towers. The lack of these steady red lights that are on constantly likely explains why birds are not attracted to wind turbines and why large-scale mortality events are not found at these types of structures. It should also be noted that a careful review by Kerlinger of papers and reports listed in Avery et al. (1980), Shire et al. (2000), and Trapp (1998) demonstrated that the only shorter communication towers known to kill large numbers of birds have been guyed towers equipped with sodium vapor lamps, hotel lights, and other bright lights that are not found on wind turbines).

Navigation lights like those required by the US Coast Guard for the lower portion of the Cape Wind WTGs have never been shown to attract birds and result in collisions.

Efficacy of Radar Use for Predicting Collision Risk at Wind Power Facilities. The final question that remains is whether radar is an accurate predictor of collision risk at wind turbines or other structures. Although various agencies and environmental organizations frequently request preconstruction radar studies at wind power facilities (Anderson et al. 1999), there does not seem to have been much in the way of validation for this method or other remote sensing methods. It is, apparently, assumed that radar data is a means of determining if migrants and other birds are at risk and if they are, how many may be at risk.

To date, no studies have demonstrated that radar data can be used to predict risk to night migrating or other birds at wind power projects. In fact, the studies needed to determine whether radar can be used to predict risk have currently been conducted at only one location. In Minnesota, where more than 3.5 million birds per year migrated over more than 200 wind turbines, postconstruction mortality studies failed to show biologically significant mortality (Hawrot and Hanowski 1997, Johnson et al. 2002). In Europe, there are also few studies and none currently available that have linked radar study results to collision frequency or degree of risk. It should further be noted that radar studies conducted in marine environments in Europe showed that waterfowl, particularly eiders and scoters, flew around turbines, even in darkness (Tulp et al. 1999). Most importantly, significant risk to birds (defined as mortality resulting in population declines) has never been documented at any wind power facility. Without significant mortality from any site, radar data cannot be assumed to be an accurate predictor or assessor of risk to birds. What will be needed is a large enough variation in the dependent variable (numbers of dead birds) and concordant variation in the behavior and number of birds (as measured by radar [or other remote sensing equipment]) that pass through or over a wind power facility.

For the above reasons, interpretation of radar data is tenuous and should not be relied upon solely to predict or assess risk. It is possible that future radar studies, if done at sites where there are very large numbers of birds and where there are turbines, may reveal a correlation between traffic rates and fatalities at wind turbines. However, until radar has been validated or reliably demonstrated as a means of predicting or assessing risk at wind turbine facilities, interpretation of data from radar studies should be done with caution.

5.0 LITERATURE CITED

Able, K.P. 1970. A radar study of the altitude of nocturnal passerine migration. Bird Banding 41:282-290.

Able, K.P. 1973. The role of weather variables and flight direction in determining the magnitude of nocturnal bird migration. Ecology 54:1031-1041.

Able, K.P. 1999. Gatherings of angels, migrating birds and their ecology. Cornell University Press, Ithaca, NY.

Avery, M., P.F. Springer, and J.F. Cassel. 1976. The effects of a tall tower on nocturnal bird migration – a portable ceilometer study. Auk 93:281-291.

Avery, M.L., P.F. Springer, and N.S. Dailey. 1980. Avian mortality at man-made structures: an annotated bibliography. U.S. Fish & Wildlife Service, FWS/OBS-80/54.

Baird, J. 1999. Returning to the tropics: the epic autumn flight of the blackpoll warbler. In K.P. Able, ed., Gatherings of angels, migrating birds and their ecology. Cornell University Press, Ithaca NY.

Berthold, P. 2001. Bird migration, a general survey. Oxford University Press, New York.

Cooper, B.A., C.B. Johnson, and R.J. Ritchie. 1995. Bird migration near existing and proposed wind turbine sites in the eastern Lake Ontario Region. Report to Niagara Mohawk Power Corporation, Syracuse, NY.

Cooper, B.A., and T. Mabee. 1999. Bird migration near proposed wind turbine sites at Wethersfield and Harrisburg, New York. Niagara Mohawk Power Corporation, Syracuse, NY.

Drury, W.H., Jr., and I.C.T. Nisbet. 1964. Radar studies of orientation of songbird migrants in southeastern New England. Bird Banding 35:69-118.

Erickson, W., G.D. Johnson, M.D. Strickland, K.J. Sernka, and R. Good. 2001. Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of collision mortality in the United States. White paper prepared for the National Wind Coordinating Committee, Avian Subcommittee, Washington, DC.

Erickson, W.P., J. Jeffrey, K. Kronner, and K. Bay. 2003. Stateline Wind Project Wildlife Monitoring Annual Report, results ofr the period July 2001-December 2002. FPL Energy, Oregon Office of Energy, and Stateline Technical Advisory Committee.

Gauthreaux, S. A., Jr. 1971. A radar and direct visual study of passerine spring migration in southern Louisana. Auk 88:343-365.

Gauthreaux, S.A., Jr. 1972. Behavioral responses of migrating birds to daylight and darkness: a radar and direct visual study. Wilson Bulletin 84:136-148.

Gauthreaux, S. A., Jr. 1980a. The influence of global climatological factors on the evolution of bird migratory pathways. In S. A. Gauthreaux, Jr. and G. Zink, conveners, Symposium on patterns of bird migration and the geographical, meteorological, and climatological aspects. XVII International Ornithological Congress, Berlin, 1980. pp. 517-525

Gauthreaux, S. A., Jr. 1980b. Direct visual and radar methods for the detection, quantification, and prediction of bird migration. Special Publication #2. Dept. of Zoology, Clemson University, Clemson, SC. Sponsored by the U. S. Air Force Office of Scientific Research.

Hawrot, R.Y., and J. M. Hanowski. 1997. Avian assessment document: avian population analysis for wind power generation regions:012. Natural Resources Research Institute. Tech. Rpt. No. NRRI/TR-97-23.

Johnson, R., and W. J. Richardson. 1982. Waterbird migration near the Yukon and Alaskan Coast of the Beaufort Sea: II Moult migration of seaducks in summer. Arctic 35:291-301.

G.D. Johnson, W.P. Erickson, M.D. Strickland, M.F. Shepherd, D.A. Shepard, and S.A. Sarappo. 2002. Collision mortality of local and migrant birds at a large-scale wind-power development on Buffalo Ridge, Minnesota. Wildlife Society Bulletin 30:879-887.

Kerlinger, P. 1995. How birds migrate. Stackpole Books, Mechanicsburg, PA. pp. 228.

Kerlinger, P. 2000. Avian mortality at communications towers: a review of recent literature, research, and methodology, 1995-2000. Report to U. S. Fish and Wildlife Service.

Kerlinger, P. 2000. Avian mortality at communications towers: a review of recent literature, research, and methodology. Report to the U. S. Fish and Wildlife Service. www.fws.gov/r9mbmo

Kerlinger, P., and F. R. Moore. 1989. Atmospheric structure and avian migration. In Current Ornithology, vol. 6:109-142. Plenum Press, NY.

Kerlinger, P., and J. Hatch. 2001. Preliminary avian risk assessment for the Nantucket Sound Wind Energy Project. Report prepared for Wind Management, L.L.C., and Environmental Science Services, Inc.

Kerlinger, P. 2002. An assessment of the impacts of Green Mountain Power Corporation's wind power facility on breeding and migrating birds in Searsburg, Vermont. July 1996-July 1998. Prep. For VT Depart. Public Service, Montpelier, VT. U. S. Department of Energy – National Renewable Energy Laboratory, NREL/SR-500-28591, Golden, CO.

Kerlinger, P. and J. Kerns. 2003. FAA lighting and bird collisions at wind turbines. Paper presented at the National Wind Coordinating Committee – Wildlife Working Group Meeting, November 17-18, 2003, Washington, DC.

Kerns, J., and P. Kerlinger. 2004. A study of bird and bat collision fatalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia: Annual Report for 2003. Prepared for FPL Energy and Mountaineer Wind Energy Center Technical Review Committee.

Larkin, R.P., and B.A. Frase. 1988. Circular paths of birds flying near a broadcasting tower in cloud. Journal of Comparative Psychology 102:90-93.

Nicholson, C.P. 2003. Buffalo Mountain Windfarm bird and bat mortality monitoring report: October 2001-September 2002. Tennessee Valley Authority, Knoxville, TN.

Nisbet, I.C.T. 1963. Measurements with radar of the height of nocturnal migration over Cape Cod, Massachusetts. Bird-Banding 34:57-67.

Nisbet, I.C.T. 1970. Autumn migration of the Blackpoll Warbler: evidence for long flight provided by regional airport. Bird Banding 41:207-240

Nisbet, I.C.T., and W.H. Drury, Jr. 1967. Scanning the sky-birds on radar, weather and migration. Massachusetts Audubon , Summer and Autumn 1967.

Nisbet, I.C.T., and W.H. Drury, Jr. 1969. A migration wave observed by moon-watching and at banding stations. Bird Banding 40:243-252.

Northrop, Devine, & Tarbell, Inc. 1995a. New England Wind Energy Station, Spring 1994 nocturnal migration study report. Report to Kenetech Windpower, Inc., Portland, ME.

Northrop, Devine, & Tarbell, Inc. 1995b. New England Wind Energy Station, Fall 1994 nocturnal migration study report. . Report to Kenetech Windpower, Inc., Portland, ME.

Ralph, C.J. 1978. Disorientation and possible fate of young passerine coastal migrants. Bird Banding 49:237-247.

Richardson, W. J. 1976. Autumn migration over Puerto Rico and the western Atlantic: a radar study. Ibis 118:309-332.

Richardson, W. J. 1979. Southeastward shorebird migration over Nova Scotia and New Brunswick in autumn: a radar study. Canadian Journal of Zoology 57:107-124.

Shire, G., K. Brown, and G. Winegrad. 2000. Communication towers: a deadly hazard to birds. American Bird Conservancy, Washington, DC.

Trapp, J. 1998. Bird kills at towers and other man-made structures: an annotated partial bibliography (1960-1998). U. S. Fish and Wildlife Service, Arlington, VA. http://migratory birds.fws.gov/issues/tower.html.

Tulp, I., Schekkerman, H., Larsen, J.K., van der Winden, J., van de Haterd, R.J.W., van Horssen, P., Dirksen, S., Spaans, 1999. Nocturnal flight activity of seaducks near the windfarm Tuno Knob in the Kattegat. Bureau Waardenburg project No. 98.100, report No. 99.64.

Veit, R.R., and W.R. Petersen. 1993. Birds of Massachusetts. Massachusetts Audubon Society, Natural History of New England Series.

Williams, T.C., J.M. Williams, P.G. Williams, and P. Stokstad. 2001. Bird migration through a mountain pass studied with high resolution radar, ceilometers, and census. Auk 118:389-403.

ATTACHMENT 1

Total Hours of TracScan Observations During the Spring and Fall

TracScan	Spring Day					Spring Night					Total Hours Observed
Date	Hours Clear	Hours Fog	Hours Rain	Hours Mist	Hours Observed	Hours Clear	Hours Fog	Hours Rain	Hours Mist	Hours Observed	
5/8/2002	15	0	0	0	15	6	0	0	0	6	21
5/9/2002	5	0	0	0	5	5	2	0	1	8	13
5/10/2002	16	0	0	0	16	4	0	3	1	8	24
5/11/2002	16	0	0	0	16	6	0	0	0	6	22
5/12/2002	0	0	0	0	0	0	0	0	0	0	0
5/13/2002	0	0	8	0	8	2	0	0	0	2	11
5/14/2002	11	0	0	2	14	2	0	4	2	8	21
5/15/2002	15	0	0	0	15	5	0	0	0	5	19
5/16/2002	13	0	0	0	13	3	0	0	0	3	16
5/17/2002	2	0	1	3	7	5	0	0	0	5	11
5/18/2002	0	0	0	0	0	0	0	0	0	0	0
5/19/2002	0	0	0	0	0	0	0	0	0	0	0
5/20/2002	11	0	0	0	11	0	0	0	0	0	11
5/21/2003	0	0	0	0	0	0	0	0	0	0	0
5/22/2002	9	0	0	0	9	0	0	0	0	0	9
5/23/2002	0	0	0	0	0	3	0	0	0	3	3
5/24/2002	16	0	0	0	16	8	0	0	0	8	24
5/25/2002	16	0	0	0	16	8	0	0	0	8	24
5/26/2002	15	0	1	0	16	6	1	0	1	8	24
5/27/2002	8	4	0	4	16	0	4	0	4	8	24
5/28/2002	9	4	0	3	15	0	0	0	8	8	23
5/29/2002	9	3	0	3	15	0	0	0	5	5	20
5/30/2002	1	3	0	2	6	0	3	0	0	3	10
5/31/2002	10	3	0	3	16	1	4	2	1	8	24
6/1/2002	0	0	0	0	0	0	0	0	2	2	2
6/2/2002	7	0	0	0	7	3	0	0	0	3	11
6/3/2002	16	0	0	0	16	8	0	0	0	8	24
6/4/2002	1	0	0	0	1	5	0	0	0	5	6
6/5/2002	14	0	2	0	16	8	0	0	0	8	24
6/6/2002	7	0	1	7	15	5	0	2	1	8	23
6/7/2002	0	0	12	0	12	0	0	5	0	5	16
Total	240	18	26	27	311	92	14	15	25	146	457

Note: Values in this table have been rounded from raw data in Appendix 5.7-J.

TracScan	Fall Day					Fall Night					Total Hours Observed
Date	Hours Clear	Hours Fog	Hours Rain	Hours Mist	Hours Observed	Hours Clear	Hours Fog	Hours Rain	Hours Mist	Hours Observed	
9/3/2002	0	0	0	0	0	0	0	0	0	0	0
9/4/2002	6	1	0	2	8	2	1	0	1	4	12
9/5/2002	1	0	0	0	1	6	0	0	0	6	7
9/6/2002	0	0	0	0	0	0	0	0	0	0	0
9/7/2002	0	0	0	0	0	1	1	0	2	4	4
9/8/2002	2	0	0	0	3	4	5	0	1	9	12
9/9/2002	12	0	0	0	12	10	0	0	0	10	22
9/10/2002	5	5	0	3	13	5	5	0	0	10	23
9/11/2002	11	0	3	0	14	4	4	1	1	10	24
9/12/2002	12	0	0	0	12	10	0	0	0	10	22
9/13/2002	13	0	0	0	13	6	0	0	0	6	19
9/14/2002	12	0	0	2	14	4	0	0	0	4	18
9/15/2002	8	0	1	1	10	3	0	1	0	4	14
9/16/2002	0	0	7	4	11	0	1	0	3	4	16
9/17/2002	14	0	0	0	14	5	1	0	4	10	23
9/18/2002	13	0	0	0	13	4	1	0	5	10	23
9/19/2002	12	0	0	0	12	5	0	0	3	8	19
9/20/2002	0	0	0	0	0	0	0	0	0	0	0
9/21/2002	0	0	0	0	0	0	0	0	0	0	0
9/22/2002	0	0	0	0	0	0	0	0	0	0	0
9/23/2002	7	0	1	0	8	4	0	0	0	4	12
9/24/2002	1	0	9	4	14	9	0	1	0	9	23
9/25/2002	11	0	0	0	11	9	0	0	0	9	20
9/26/2002	12	0	2	0	14	6	0	4	0	10	24
9/27/2002	6	2	5	1	14	2	0	6	1	9	23
9/28/2002	14	0	0	0	14	9	0	0	1	10	23
9/29/2002	14	0	0	0	14	9	0	0	0	9	24
9/30/2002	14	0	0	0	14	10	0	0	0	10	24
Total	198	8	28	18	252	125	18	12	22	177	429

Note: Values in this table have been rounded from raw data in Appendix 5.7-J.

ATTACHMENT 2

Total Hours of Vercat Observations During the Spring and Fall

Vercat	Spring Day					Spring Night					
Date	Hours Clear	Hours Fog	Hours* Rain	Hours Mist	Hours Observed	Hours Clear	Hours Fog	Hours* Rain	Hours Mist	Hours Observed	Total Hours Observed
5/8/2002	15	0	0	0	15	6	0	0	0	6	20
5/9/2002	11	0	0	0	11	5	2	0	1	8	19
5/10/2002	5	0	0	0	5	1	0	2	1	4	9
5/11/2002	0	0	0	0	0	0	0	0	0	0	0
5/12/2002	0	0	0	0	0	0	0	0	0	0	0
5/13/2002	0	0	2	0	2	2	0	0	0	2	4
5/14/2002	4	0	0	2	6	0	0	3	2	5	11
5/15/2002	1	0	0	0	1	3	0	0	0	3	4
5/16/2002	15	0	0	0	15	8	0	0	0	8	23
5/17/2002	11	0	2	3	16	6	0	2	0	8	24
5/18/2002	0	0	2	0	2	0	0	5	0	5	7
5/19/2002	0	0	0	0	0	0	0	0	0	0	0
5/20/2002	7	0	0	0	7	2	0	0	0	2	9
5/21/2003	14	0	0	0	14	8	0	0	0	8	22
5/22/2002	15	0	0	0	15	8	0	0	0	8	23
5/23/2002	16	0	0	0	16	8	0	0	0	8	24
5/24/2002	15	0	0	0	15	5	0	0	0	5	20
5/25/2002	8	0	0	0	8	3	0	0	0	3	11
5/26/2002	15	0	1	0	16	6	1	0	1	8	24
5/27/2002	8	4	0	3	16	0	4	0	4	8	24
5/28/2002	9	4	0	3	16	0	0	0	8	8	24
5/29/2002	9	4	0	3	16	0	3	0	5	8	24
5/30/2002	4	8	0	3	16	0	7	0	1	8	24
5/31/2002	10	3	0	3	15	1	4	2	1	8	23
6/1/2002	14	1	0	1	16	4	0	0	4	8	24
6/2/2002	14	0	0	1	15	8	0	0	0	8	22
6/3/2002	16	0	0	0	16	7	0	0	0	7	23
6/4/2002	15	0	0	0	15	5	0	0	0	5	20
6/5/2002	10	0	0	0	10	3	0	0	0	3	13
6/6/2002	7	0	1	7	15	4	0	0	1	5	20
6/7/2002	0	0	0	0	0	0	0	0	0	0	0
Total	267	24	8	31	330	103	21	14	27	165	495

* This data may not be useful due to the inability of the Vercat to identify targets during rain.

Note: Values in this table have been rounded from raw data in Appendix 5.7-J.

Vercat	Fall Day					Fall Night					
Date	Hours Clear	Hours Fog	Hours* Rain	Hours Mist	Hours Observed	Hours Clear	Hours Fog	Hours* Rain	Hours Mist	Hours Observed	Total Hours Observed
9/3/2002	1	0	0	3	4	1	0	0	3	4	8
9/4/2002	6	2	0	4	12	2	5	0	2	9	21
9/5/2002	11	0	0	0	11	8	0	0	0	8	19
9/6/2002	0	0	0	0	0	3	0	0	0	3	3
9/7/2002	12	1	0	0	13	4	4	0	2	10	23
9/8/2002	4	0	0	0	5	4	5	0	1	9	14
9/9/2002	12	0	0	0	12	10	0	0	0	10	22
9/10/2002	5	5	0	3	13	5	5	0	0	10	23
9/11/2002	4	0	3	0	7	4	4	1	1	10	17
9/12/2002	13	0	0	0	13	9	0	0	0	9	22
9/13/2002	14	0	0	0	14	8	0	0	0	8	22
9/14/2002	0	0	0	0	0	2	0	0	0	2	2
9/15/2002	9	0	1	1	11	5	0	1	0	6	18
9/16/2002	0	0	7	4	11	0	1	0	3	4	15
9/17/2002	13	0	0	0	13	4	1	0	1	6	18
9/18/2002	9	0	0	0	9	4	0	0	0	4	13
9/19/2002	13	0	0	0	14	5	0	0	3	8	21
9/20/2002	0	0	0	0	0	0	0	0	0	0	0
9/21/2002					0					0	0
9/22/2002					0					0	0
9/23/2002	7	0	1	0	8	4	0	0	0	4	12
9/24/2002	0	0	9	3	13	9	0	1	0	9	22
9/25/2002	12	0	0	0	12	10	0	0	0	10	22
9/26/2002	12	0	2	0	14	6	0	4	0	10	24
9/27/2002	6	2	5	1	14	2	0	6	2	10	23
9/28/2002	14	0	0	0	14	9	0	0	1	10	24
9/29/2002	14	0	0	0	14	9	0	0	0	9	23
9/30/2002	14	0	0	0	14	10	0	0	0	10	24
Total	206	11	29	19	264	136	25	12	18	192	456

* This data may not be useful due to the inability of the Vercat to identify targets during rain.

Note: Values in this table have been rounded from raw data in Appendix 5.7-J.

ATTACHMENT 3

Altitude Distribution (AMSL)

By Size Class

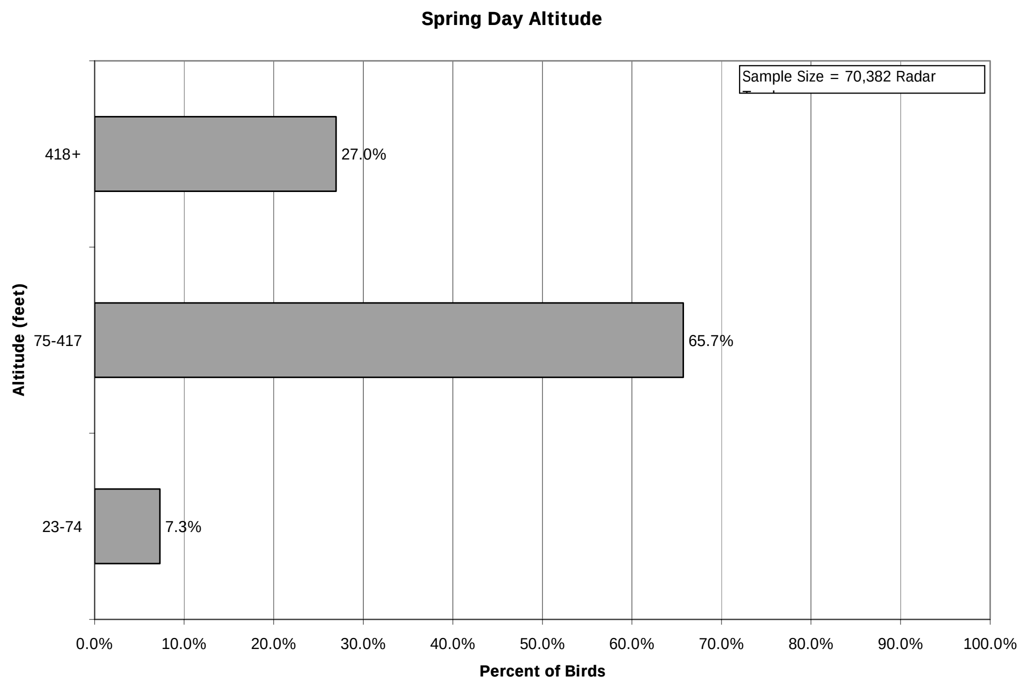
Spring and Fall

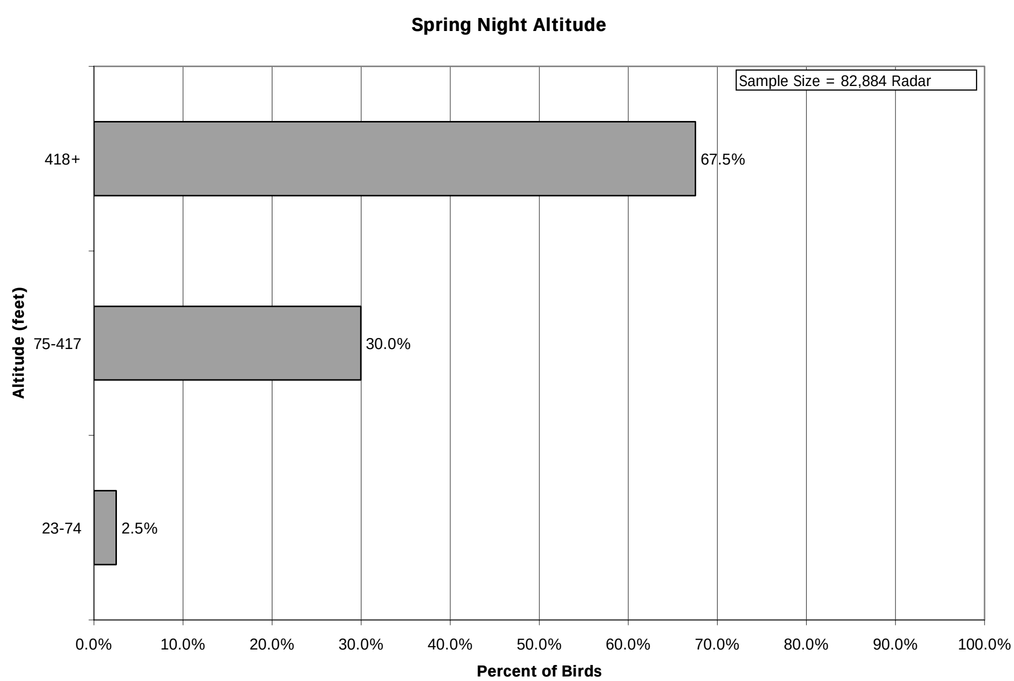
Altitude (AMSL) distribution of birds by size class from MARS data recorded in spring and fall study periods.

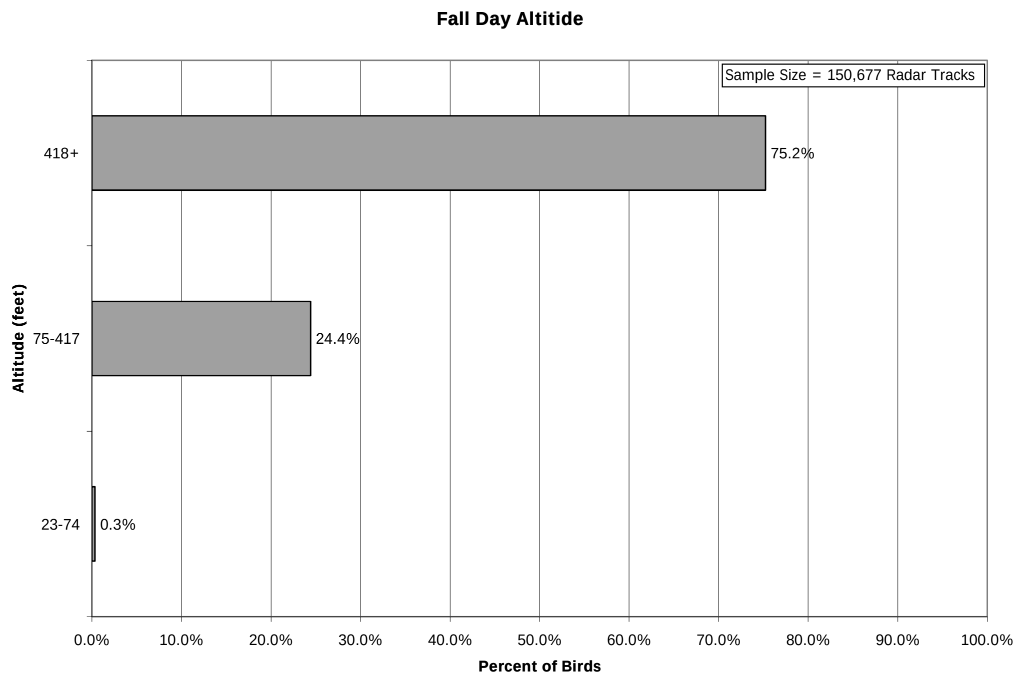
	Target Type				
Altitude	Small	Medium	Large	Flock	Total
Spring Day					
23-74	3622	1028	341	146	5137
75-417	29024	9735	4587	2922	46268
418+	15542	2033	796	606	18977
Total	48188	12796	5724	3674	70382
Spring Night					
23-74	1450	458	127	36	2071
75-417	18046	4834	1244	714	24838
418+	44549	10571	577	278	55975
Total	64045	15863	1948	1028	82884
Spring Total	112233	28659	7672	4702	153266
Fall Day					
36-74	273	133	50	52	508
75-417	23156	9104	2772	1783	36815
418+	87058	20733	3682	1881	113354
Total	110487	29970	6504	3716	150677
Fall Night					
36-74	63	29	5	3	100
75-417	14461	4527	562	226	19776
418+	134450	28408	3811	818	167487
Total	148974	32964	4378	1047	187363
Fall Total	259461	62934	10882	4763	338040

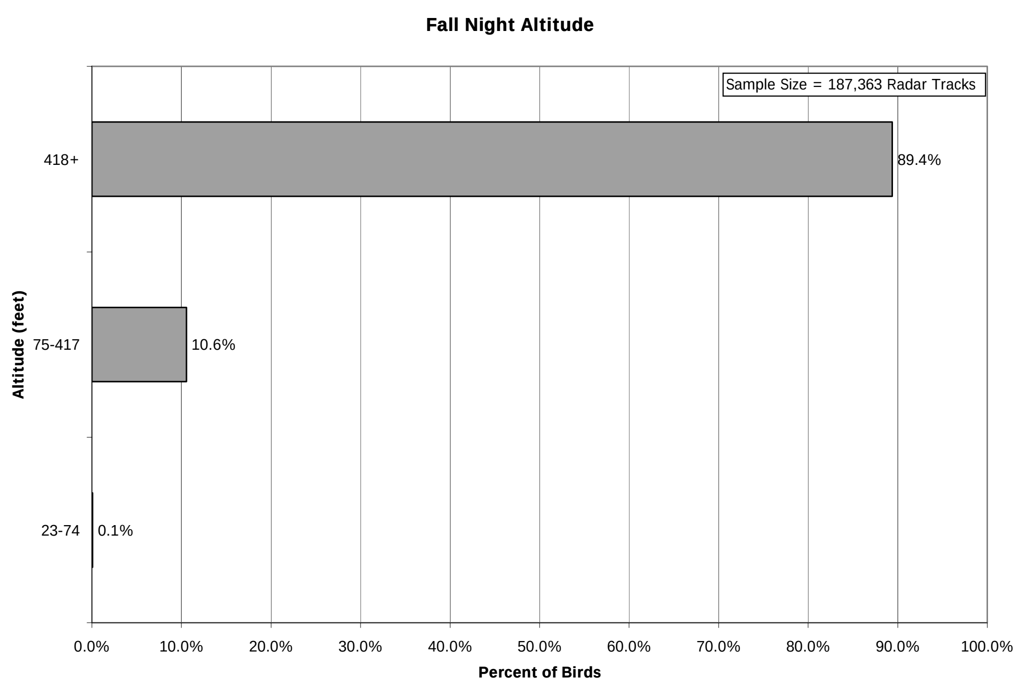
ATTACHMENT 4

Percentage of Targets in the Different Altitude Strata Spring and Fall


Spring Day Altitude
Sample Size = 70,382 Radar
418+
75-417
23-74
27.0%
65.7%
7.3%
Altitude (feet)
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
70.0%
80.0%
90.0%
100.0%
Percent of Birds


Spring Night Altitude
Sample Size = 82,884 Radar
418+
75-417
23-74
67.5%
30.0%
2.5%
Altitude (feet)
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
70.0%
80.0%
90.0%
100.0%
Percent of Birds

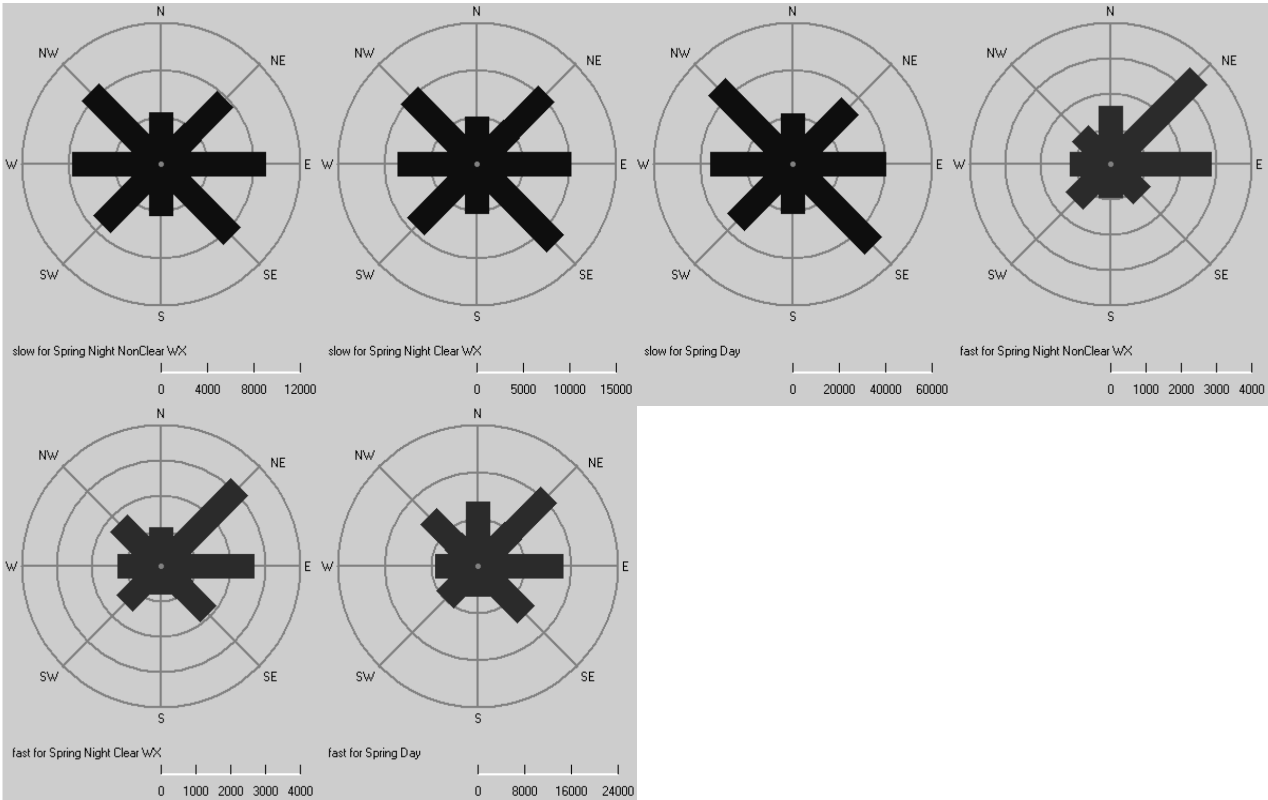

Fall Day Altitide
Sample Size = 150,677 Radar Tracks
418+
75.2%
75-417
24.4%
23-74
0.3%
Altitude (feet)
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
70.0%
80.0%
90.0%
100.0%
Percent of Birds

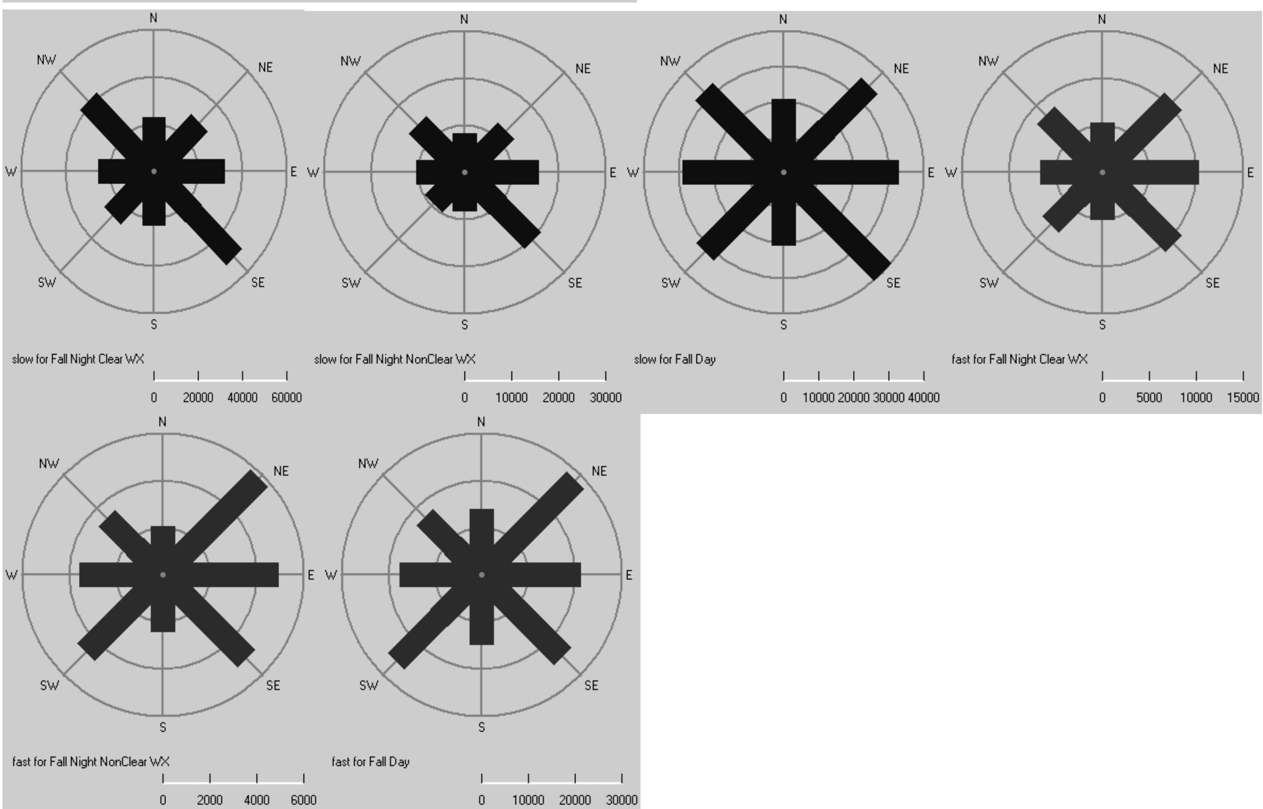

Fall Night Altitude
Sample Size = 187,363 Radar Tracks
418+
89.4%
75-417
10.6%
23-74
0.1%
Altitude (feet)
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
70.0%
80.0%
90.0%
100.0%
Percent of Birds

ATTACHMENT 5

Compass Rose Plots

Spring and Fall


slow for Spring Night NonClear WX
0 4000 8000 12000
slow for Spring Night Clear WX
0 5000 10000 15000
slow for Spring Day
0 20000 40000 60000
fast for Spring Night NonClear WX
0 1000 2000 3000 4000
fast for Spring Night Clear WX
0 1000 2000 3000 4000
fast for Spring Day
0 8000 16000 24000
N NE E SE S SW W NW


slow for Fall Night Clear WX
0 20000 40000 60000
slow for Fall Night NonClear WX
0 10000 20000 30000
slow for Fall Day
0 10000 20000 30000 40000
fast for Fall Night Clear WX
0 5000 10000 15000
fast for Fall Night NonClear WX
0 2000 4000 6000
fast for Fall Day
0 10000 20000 30000
N NE E SE S SW W NW